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United States
Department of
Agriculture

Forest
Service

General
Technical
Report
WO-52



Making Our Forests and Rangelands More Productive

1985 Research Accomplishments





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September 1986

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Foreword

This year's Research Accomplishments Report highlights over 60 major research efforts that came to fruition during 1985. Our scientists, together with cooperators from universities and Federal and State agencies, are working on these and other important topics to improve our ability to manage America's forests and rangelands. Forest Service research falls into six categories: Environment, Insects and Disease, Fire/Atmospheric Sciences, Timber Management, Resource Economics, and Products and Harvesting. Both the research highlights and the list of research-related publications distributed since late 1984 are divided along these subject-matter lines.

Our investigators follow generally accepted procedures of analyzing the problem in question, designing and executing experiments, and then







testing and applying their findings. In cases where much research has already been done on parts of problems, they gather and synthesize earlier findings that have yet to be applied. A major goal of our research is to uncover new ways to stretch limited forest- and range-management dollars.

Because basic research can open whole new areas in the use of natural resources, it continues to receive strong emphasis in our program. Forest Service research in biotechnology, for example, led to the discovery of an enzyme that degrades the lignin in wood. Breaking down this woody, fibrous material has been a problem for papermakers. Our discovery and applications-oriented research building on it should lead to significant savings for industry and, ultimately, the consumer.

Our economics people have confirmed for the coming century a scenario of increasing population and subsequently increased demands on our natural resources base. Complicating this picture is the likelihood of reduced Federal spending for research as the Nation comes to grips with balancing the budget. Obviously the need for innovative basic and applied research will become even more acute as time passes. With the knowledge described in these pages already in hand, our scientists look to the 21st century for solutions to today's—and tomorrow's—forest-management problems.



R. MAX PETERSON
Chief

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Acknowledgment

Janet Searcy, on detail to the office of the Deputy Chief for Research, Washington, DC, edited and coordinated production of this report.

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Environment

Water Quality Associated With Southern Forest Practices and Conditions

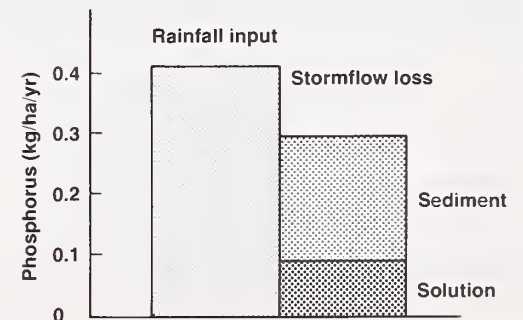
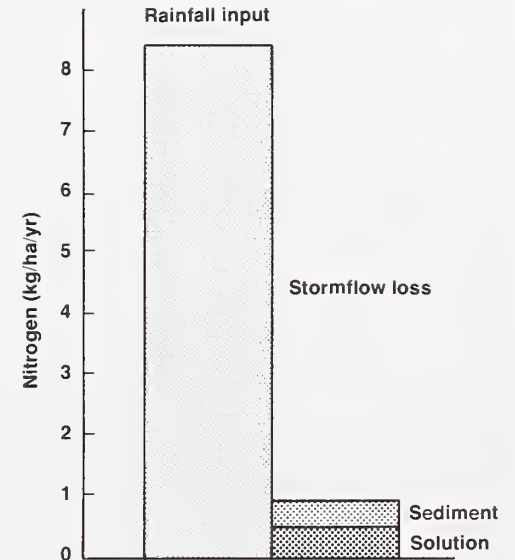
Water-quality studies have included measures of atmospheric inputs of nitrogen (N), phosphorus (P), and other elements and compounds as well as their amounts in runoff from small disturbed and undisturbed forested catchments. The quality of water leaving undisturbed forests provides information needed for establishment of water-quality standards and a base with which to determine impacts of disturbances. Comparisons of nutrient inputs and losses also are useful for assessing changes in site productivity.

Results from studies at three separate locations indicate that undisturbed loblolly pine plantations, which cover substantial areas of the southern Coastal Plain, protect water quality and maintain site productivity by retaining a significant portion of N and P inputs and yielding only small amounts of sediment. Results also show that sediment transport of N and P, which is often overlooked, can be important.

Research on both the Coastal Plain and mountains of the Interior Highlands has demonstrated that, properly applied, harvesting, including clearfelling, is acceptable over a wide range of southern soils and topography. A variety of mechanical site preparation practices are acceptable in the Interior Highlands, but they must be used with caution in the Coastal Plain, where channels are unstable.

Numerous water-quality studies of forested catchments were summarized in a regional symposium. This information can be used to develop guidelines to protect water quality while harvesting and regenerating southern forests.

Means for five catchments represent nitrogen and phosphorus input and loss relationships and demonstrate the relative importance of nutrient transport by sediment from small pine-covered coastal plain catchments.



Not All Erosion Is Bad

The statement may sound somewhat heretical, but sometimes erosional processes are necessary before a landscape can be stabilized. Research on the Alkali Creek watershed in western Colorado illustrates the point.

In the early 1960's, gully stabilization research was started by Rocky Mountain Station scientists. The basic structure of the overgrazed, eroding watershed consisted of alternate layers of sandstone and high-sodium shale. When the protective sandstone caps wore away, the exposed shale eroded rapidly. A series of check dams was constructed to prevent further downcutting in the expanding gully system.

Evaluations over the ensuing 20 years have shown that rehabilitation is more than a matter of damming gullies—it is actually a three-stage process. First, the steep, bare, high-sodium gully banks disintegrate. The check dams help prevent the sloughed soil material from being flushed down the channel. Subsequent weathering and leaching greatly reduce the sodium content of the accumulating soil in the channel bottom. Finally, when enough sodium has been leached from

the eroded material, plant cover develops and stabilizes the channel.

Erosion of the steep, high-sodium banks and subsequent leaching of the sodium from the material deposited in



the channel bottom are the key factors in stabilizing this watershed. A perennial stream now flows from a formerly ephemeral gully, and suspended sediment has been reduced by 95 percent.



This high-sodium gully bank (left) had to disintegrate and have most of the sodium leached from the sloughed material before vegetation could stabilize the channel (right).

Low-Cost Logging Roads That Protect Mountain Watersheds

In steep terrain, construction of access roads is a major expense in logging and in supplying roads for vacation homes. Furthermore, if they are poorly designed, such roads often cause excessive stream sedimentation. As a result, there is a big demand in the Appalachian Mountains for environmentally acceptable roads that can be built and maintained inexpensively.

Working closely with engineers, hydrologists at the Southeastern Station have developed design standards for mountain access roads.

Depending upon conditions and road uses, they recommend seeding of grass or application of gravel to the road surface. They also recommend seeding of fill slopes, placement of brush barriers, and maintenance of filter strips below the road. To reduce costs for ditches and culverts, they recommend use of broad-based dips to pass water across the road.

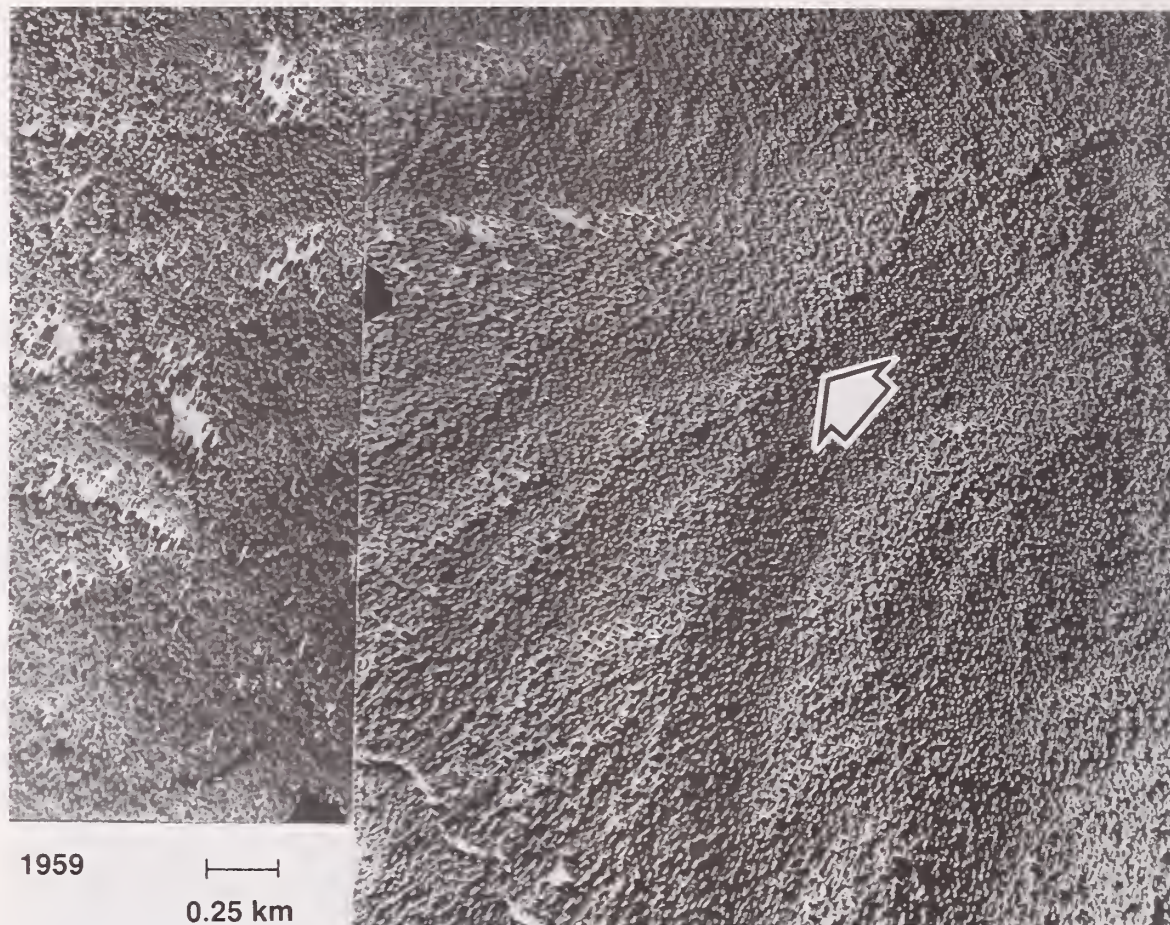
The recommendations make it possible to minimize the environmental disturbance associated with low-cost access roads.



Technique Developed To Evaluate Off-Site Effects of Logging on Streams

Do timber harvest activities affect the physical structure of stream channels downstream from the logging activity? Answers to this question are important in the steep forest lands of the Pacific Northwest because of the potential consequences to aquatic resources. Research has shown that timber harvest in this region can affect the timing, rate, and volume of water and sediment movement in streams. But determining the effect of such changes on the physical structure of streams (stream channel morphology) has been more difficult.

To address this problem, researchers at the Pacific Northwest Station developed a technique that uses information from aerial photographs to determine the extent of direct linkage between channel conditions and upstream logging activity. Aerial photos taken before and after a major flood in 1964 indicated that many streams in the western Cascades of





Oregon had experienced a dramatic enlargement of the riparian corridor during the storm. Scientists believed that the patterns of these openings could be used to "fingerprint" the channel for various types of disturbance.

For example, they thought channels that had experienced landslides along with high flows would have larger, more extensive openings than channels that had experienced only high flows. Measurements made on the aerial photos made it possible to relate channel openings to specific water and sediment transport processes and to evaluate the degree to which these openings were related to logging activities. This technique gives forest managers a rapid and inexpensive way to compare watersheds with different management treatments and to analyze changes in watershed conditions over time.

Aerial photographs of the same creek before and after a 1964 storm show marked enlargement of the riparian corridor associated with landslides from forests and roads.

Blowing Snow: Tough Enemy or Valuable Resource?

Blowing snow can be a valuable resource on the High Plains, but it can also be fierce and tough to harness. Using miniature fences and barriers, scientists at the Rocky Mountain Station have designed structural systems to trap snow where it can be used to good advantage, and to deflect it from areas to be sheltered.

Solid artificial barriers have commonly been used to protect livestock from blizzard winds, but if they aren't designed properly, they sometimes cause drifts that bury the animals they were designed to protect. By studying models during storms on a frozen lake, scientists were able to evaluate several variables and found a 90-degree V-shaped shelter was optimum. Semicircular shelters were also good and are more economical, but some snow did accumulate in the sheltered area.

To be most effective, the shelters should be tall—12 feet or more in height—with a width or diameter not exceeding 15 times the height. The height is necessary because the shelters' snow-deflecting efficiency will decrease if the upwind drift approaches the top of the barrier.

To trap snow to help fill a stock pond, the researchers' models showed, surprisingly, that the embankment should be built with a semicircular opening that faces into the wind. Snow accumulation can then be maximized by building a 50-percent



Snow drift formed by a 1/30 scale model of a livestock shelter.

porous, wood-slat snow fence upwind from the pond. This research is an extension of earlier studies that showed how to engineer large snow-trapping systems to protect highways.



Snow accumulation is maximized by building a snow fence on the upwind side of a pond with a downwind embankment.

Predicting Landslide Hazards After Logging in Snow Accumulation Zones

How does clearcutting affect ground-water levels in the steep, mountainous regions of the West? This question is important because ground-water levels are the primary factor leading to landslides in these areas.

Scientists at the Intermountain Station evaluated the effects of clearcuts on ground-water levels on steep, granitic soils in Idaho. Ground-water levels in many mountainous areas are unique because they are caused by snowmelt rather than rainfall, and they are not the result of fluctuations in permanent ground-water levels. The Station study determined how ground-water levels varied both before and after timber harvest by clearcutting.

The study found that logging increased total snow accumulation and snowmelt rates, causing increases in ground-water level ranging from 40 to 70 percent. The frequency of peak ground-water levels was also increased up to 10 times by clearcutting. The information from this study will aid managers in predicting landslide hazards following logging in snow zones.

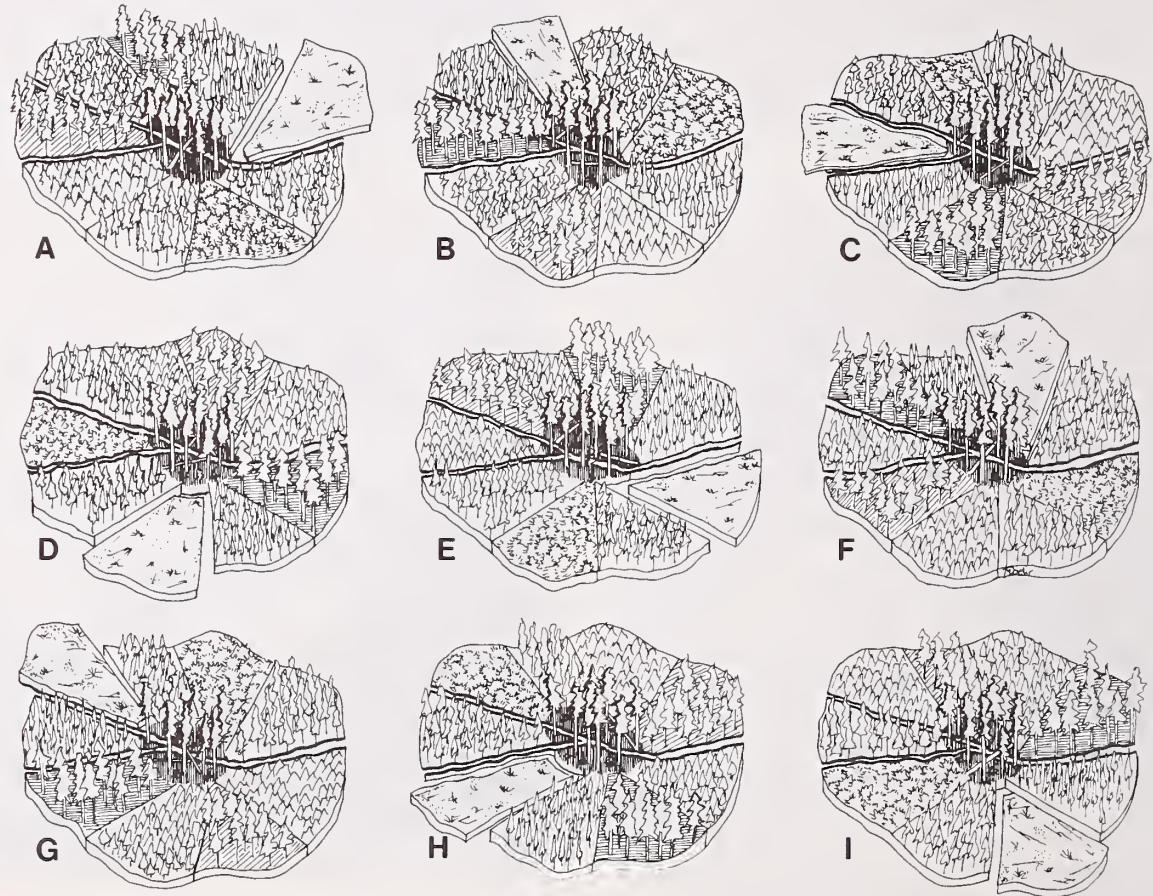


The amount of snow accumulation and the rate of snowmelt are important factors regulating landslides in clearcut areas in the northern Rockies.

Maintaining Biotic Diversity in Douglas-Fir Forests

Old-growth forests of the Douglas-fir region are a valuable resource from many points of view, including timber and wildlife. Management of this resource is hindered by a lack of knowledge and guidelines of how to maintain wildlife dependent on old-growth forests. Larry D. Harris, with support and cooperation from the Pacific Northwest Station, has written a book titled "The Fragmented Forest" (University of Chicago Press, 1984), which addresses the problem of preserving biotic diversity in Douglas-fir forests of the Pacific Northwest.

"The Fragmented Forest" offers a set of guidelines for forest planning based on island biogeographic theory. The concept is that patches of old-growth forests are similar in many respects to oceanic islands because they are surrounded by a young, managed forest that may be a hostile environment for some species.



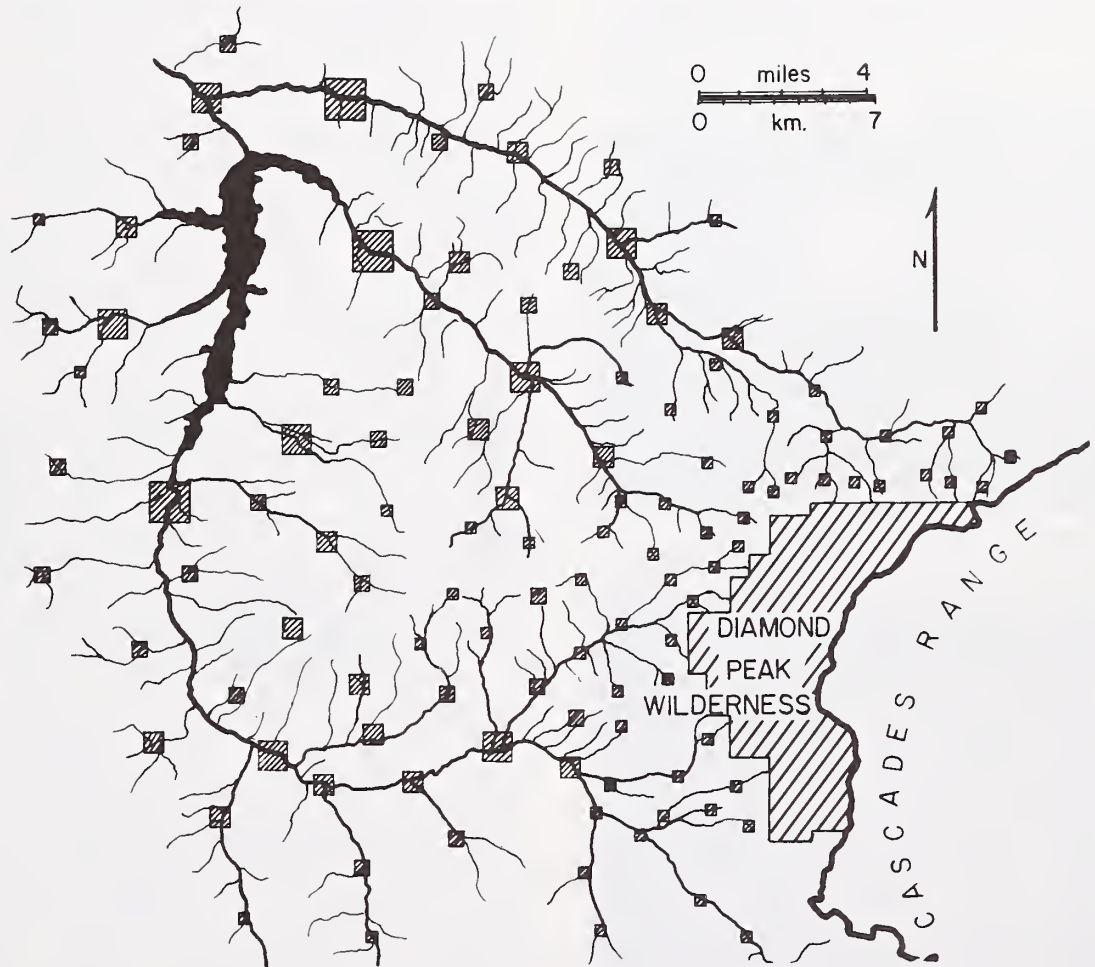
A patch of old-growth surrounded by a long rotation island that is cut in a programmed sequence to assure that 66 percent of the buffer zones in the island are over 100 years old and that the 33 percent remaining provide forage and

habitat for species that use early successional changes. (Reprinted by permission from "The Fragmented Forest," by Larry D. Harris, The University of Chicago Press, 1984.)

Harris discusses the applicability of island biogeographic theory to old-growth habitat islands and evaluates management alternatives with regard to total old-growth forest area, the size of old-growth patches and their number, and their spacing and placement in the landscape. He concludes with a strategy for maintaining biotic diversity through the establishment of long-rotation islands with a core area of old-growth. He further suggests that the long-rotation islands be placed adjacent to riparian strips that could serve as travel corridors to facilitate movement of animals throughout the network of islands.

The book is timely and will be valuable to forest managers and planners as they make decisions affecting the harvest of old-growth forests in the Pacific Northwest.

A potential spatial and size-frequency distribution of different-sized old-growth islands along riparian strips at progressively greater distances from a present wilderness area in the Willamette National Forest, Oregon. (Reprinted by permission from "The Fragmented Forest.")

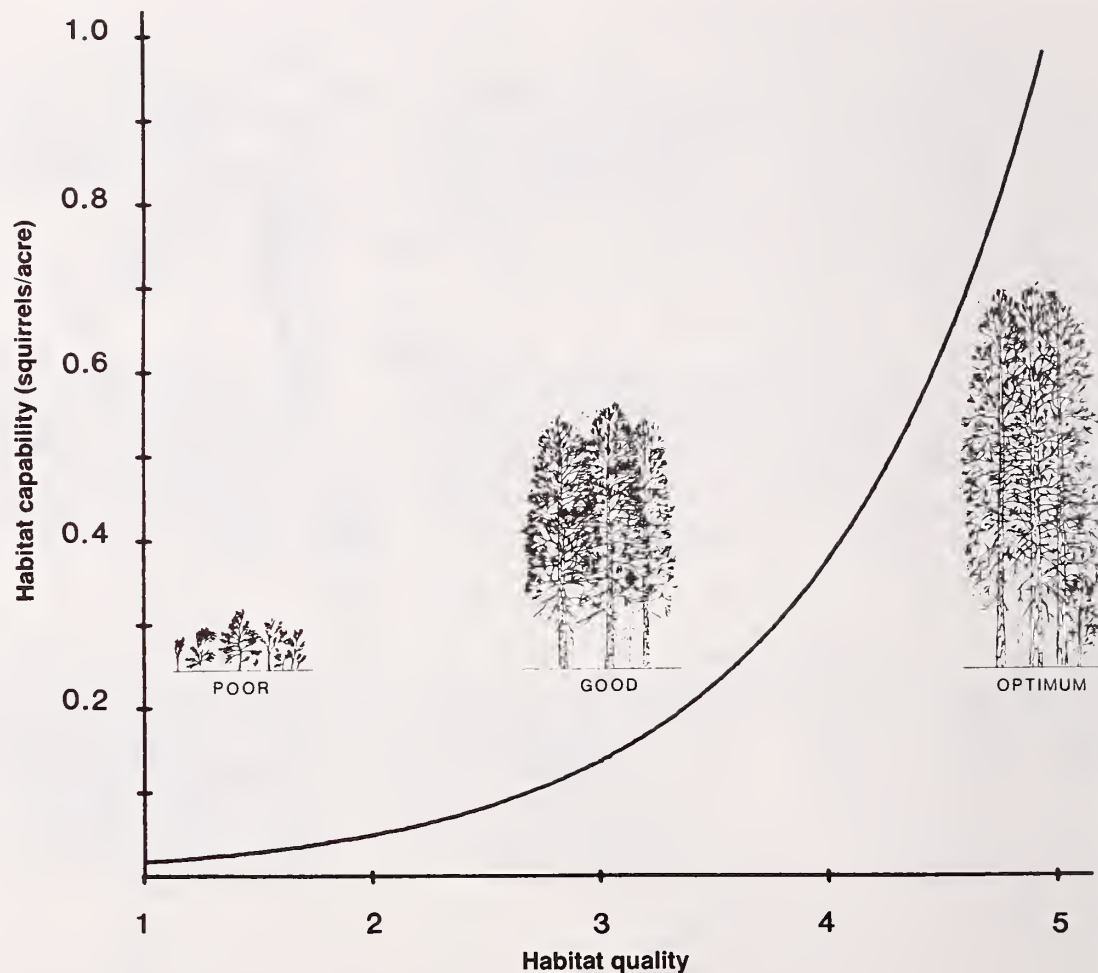


A Wildlife Species Habitat Model for Forest Managers

Rocky Mountain Station wildlife researchers have developed a new habitat model for the Abert squirrel, for use in uneven-aged ponderosa pine in the Southwest. Five habitat quality classes, based on tree size, density, and dispersion pattern, describe a stand's capability to foster squirrels.

The model is especially useful because data for estimating squirrel potential can come from existing and future timber inventories. Forest managers can therefore consider squirrels directly when planning timber harvests. Because the squirrel is almost totally dependent on small groups of ponderosa pine with interlocking crowns, high-quality squirrel habitat can be maintained through group selection harvesting. Good habitat can be maintained under shelterwood harvesting. Managers can also plan ahead for squirrel habitat when thinning sapling or pole stands.

Station researchers believe that the general approach in developing the squirrel habitat model—basing habitat quality on easily measured (and manipulated) tree and stand characteristics—has broad potential for other forest wildlife species.



Habitat capability depends on small groups of ponderosa pine with interlocking crowns.

New Ways To Improve Habitat for an Endangered Species

The Kirtland's warbler is an endangered species that is restricted to a small breeding range within State and National Forests in northern Lower Michigan. The population of this species is thought to be limited in part by the amount of suitable habitat available in Michigan. Recent research at the North Central Station has given State and Federal managers new information about Kirtland's warbler habitat requirements, the role of fire in managing the habitat, and population dynamics.

Kirtland's warblers are concentrated in a few large breeding areas, each of which provides suitable habitat for only 10 to 14 years. So habitat must be continually regenerated through timber harvesting and management. Typically, the warbler has occupied dense jack pine stands around 6 to 15 feet tall that originated from natural seeding following wildfire. Plantations are also used, including a few red pine stands. But most logged, unburned jack pine stands stocked by natural regeneration are not dense enough for breeding warblers. In unusual cases where trees are tall and dense enough in unburned stands, Kirtland's warbler can breed successfully. For example, 20 percent of Kirtland's warbler males counted

between 1971 and 1983 were found in unburned stands, but populations were low in most of them. In fact, warbler densities are generally low in burned or unburned stands that are sparsely stocked with pine trees. Researchers have found that male Kirtland's warblers in this marginal habitat are often unmated and may abandon such habitat more often than suitable habitat. Tree stocking recommendations are being tested through experimental plantings.

In the past, suitable ground cover for nesting sites has been considered the major requirement and fire has been thought necessary to create appropriate habitat. Current research suggests that tree crown cover is the key factor limiting stand occupancy, and that ground-cover composition is primarily affected by shade of tree crowns. Thus, burning may not be necessary for regenerating Kirtland's warbler habitat. In fact, fire may have little influence on ground cover by the time stands are old enough (7 to 12 years) for warbler occupancy. The few days suitable for burning and the associated risk of uncontrolled fire have produced a backlog of stands that need to be regenerated. Because our research indicates that fire is probably not necessary to create

suitable habitat, management strategies are now being developed as alternatives to fire-based methods to create habitat for Kirtland's warbler.



Adult male Kirtland's warbler in jack pine.



Kirtland's warbler breeding areas are part of multiple-use management.

Endangered Puerto Rican Parrot Population Increases

The wild population of the endangered Puerto Rican parrot reached a low of 13 birds in 1975 but has gradually and steadily grown; in 1985 it reached a record of 65 parrots (36 in the wild and 29 in a research aviary). The positive response of this population is a result of a cooperative field and aviary research program between the Forest Service, U.S. Fish and Wildlife Service, and the Puerto Rico Department of Natural Resources. In the field, scientists found that natural cavities are a limiting factor in the parrot's reproductive success. So, to increase reproduction, natural cavities were deepened, made waterproof, and redesigned to minimize human and animal predation. Artificial cavities were designed and installed in traditional parrot areas to encourage nesting, especially in younger parrots. In the aviary, reproduction by captive Puerto Rican parrots was enhanced through dietary controls, pair bonding, and egg-manipulation experiments. Artificial insemination has begun and appears to be the most promising technique for bolstering the number of captive-reared parrots.

Two significant events during the 1985 breeding season greatly increased optimism about the recovery of the

Puerto Rican parrot. Egg fertility, which had shown a steady decline for the past 3 years, once again reached the 100-percent level observed prior to 1982. A new breeding pair, using a project-provided nest site, fledged chicks. In addition, many additional parrot pairs were observed holding territories in and around traditional nesting areas, suggesting that young parrots are coming into breeding condition.

Radio-telemetry techniques were used by project biologists for the first time in 1985 to track three wild-produced and three captive-reared parrot chicks. Invaluable information was obtained on chick dispersal, integration into the wild flock, daily and seasonal movements, and first-year mortality as a result of environmental and predation pressures.

The outlook for recovery of the Puerto Rican parrot is promising. Recent advances and implementation of artificial insemination and radio-telemetry techniques should greatly increase both the number of parrot chicks introduced into the wild and the prognosis for their survival during the first year.



The white-tailed deer has made a remarkable recovery in the latter half of this century and now is probably the number one big-game animal in the world. The management information generated by research from the Nacogdoches [TX] Laboratory of the Southern Forest Experiment Station has played a part in this success story. Scientists there identified the physiological needs of deer and defined the habitat suitability of forest stands. Investigators quantified the seasonal production and nutrition of forage, mushrooms, and hard and soft mast in varied stands and passed along this information to other scientists and land managers.

A notable achievement in transferring biological and management information to users was the book "White-Tailed Deer: Ecology and Management," edited by Lowell K. Halls and published by

the Wildlife Management Institute. With sections written by 72 deer experts, the text covers biology and ecology, population management, populations and habitat, research and management, benefits, and management needs and opportunities. It synthesizes technical biological information, especially from the last 30 years, and presents it in easily understood language to managers and lay audiences.

"White-Tailed Deer" is the most comprehensive treatment of this species and has been acknowledged as the definitive volume on the white-tailed deer. It was honored in 1985 with The Wildlife Society's Editorship Book Award.



Habitat Conditions Determined for Moose in Alaska

Moose in interior Alaska rely primarily on six different willow species for summer forage, according to one study conducted by researchers at the Pacific Northwest Station's Institute of Northern Forestry in Fairbanks. The study produced the first data available about the food preferences and habitat choices of moose in summer and will be invaluable in developing resource-management models to meet wildlife needs.

Bulls and cows with calves selected very different habitat types for their foraging activities. Cows used areas with heavier tree cover and fewer shrubs; bulls tended to use dense shrub stands above timberline.

During early summer, moose fed up to 12 hours a day—about twice as long as during midwinter. Daily activity, forage intake, forage turnover, and fat deposition were all at maximum levels in early summer as moose recovered from the previous winter and prepared for the next one. Shrubs exposed to full sunlight during long summer days produced leaves with protein contents up to 20 percent. Plant communities in the study area showed few effects from wildfire during the past 50 years, and their rate of successional change was very slow.



Bull moose in Alaska tend to forage in dense shrub stands, essentially above the timberline.

Management recommendations may include protection of some stands and prescribed burning of others to reduce overstory density and stimulate willow production. Such recommendations

would have to be part of fire-management plans for Alaska, where wildfires have historically been widely suppressed.

Chenopods are a family of plants with many physiological, morphological, and genetic adaptations and characteristics that enable them to survive and even flourish throughout the world in highly stressful conditions of moisture, salinity, soil, pH, temperature, and animal use.

Chenopod plants are especially valuable for revegetation of harsh, highly disturbed sites, particularly in areas suffering from desertification. In 1985 the Intermountain Station issued a symposium proceedings containing 52 papers that describe aspects of distribution, systematics, genetics, ecological relationships, physiology, seed physiology, seed technology, animal relationships, and revegetation of Atriplex and related Chenopods. Many of these management-oriented papers emphasize shrubs of the Western United States.



A seed production orchard of the improved cultivar "Rincon" fourwing saltbush (Atriplex canescens).

How can productivity of vast acreages of intermountain rangelands be restored and maintained? Scientists, cattlemen, and politicians have been concerned about western rangelands at least since the 1930's. This concern led to a long-term research effort by Intermountain Station scientists.

Their publications on salt-desert shrub rangelands and on the Benmore Experimental Range summarize the most important research findings accumulated for these areas over the past 40 to 50 years. These publications are part of a major technology transfer effort on management of intermountain rangelands. Each includes alternative management practices applicable to vast acreages of western rangelands.



Restoring the Apache Trout

The Apache trout (formerly known as the Arizona native trout) is one of the rarest trout in the West. Distribution of this unique, beautiful fish—probably never very widespread—is now limited to a few cool mountain streams in east-central Arizona.

The existence of the Apache trout is threatened by habitat destruction, displacement by other species, and hybridization with other trout. Because the species needs colder water than most trout, it can be displaced by more tolerant brown and brook trout when protective streamside cover is reduced by logging, grazing, or other disturbance.

The most insidious threat, however, could easily carry over into ambitious projects to restore the trout over much of its original range. The Apache trout hybridizes readily with rainbow trout, which have been introduced indiscriminately throughout the West. Because the two species are closely related, their hybrid offspring are fertile and can reproduce. Remaining Apache trout in some streams, therefore, are no longer genetically "pure" and carry some characteristics of both species.

To help assure that restoration projects really stock pure Apache trout, fisheries biologists at the Rocky Mountain Station have completed an extensive taxonomic evaluation of the trout in its major remaining strongholds. Careful study of 650 trout from 45 streams showed that various conventional measurements (e.g., of fin lengths) weren't good enough to establish genetic purity. Instead, such characteristics as

number of vertebrae and number of scales above the vertical line must be evaluated. Using these characteristics, the scientists pinpointed trout in streams on the Fort Apache Indian Reservation as being of greater purity than many of those on nearby National Forest lands. The Apache Trout Interagency Recovery Team is now using the results of this research to prevent the loss of this unique fish.

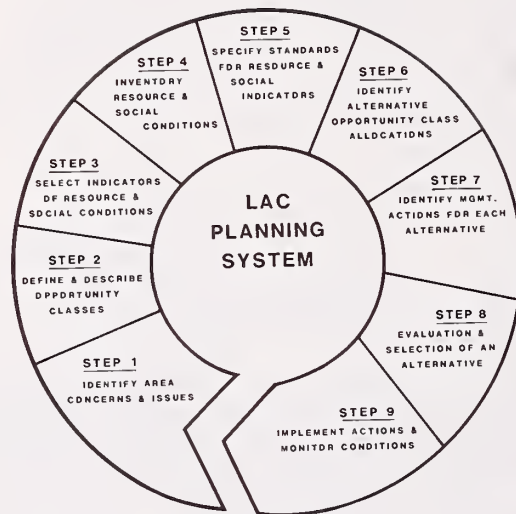


Restoration of the Apache trout must include careful genetic study.

A New Management System To Determine the Carrying Capacity of Wilderness

Most wilderness managers consider their major challenge to be determining wilderness carrying capacity for recreational use and managing for it. Despite increased knowledge about the severity of recreation's impacts and visitor preferences for solitude—the two primary components of carrying capacity—determining the maximum allowable number of recreational visitors has proven unusually difficult.

Scientists at the Intermountain Station have developed the Limits of Acceptable Change approach, or LAC, which solves the carrying-capacity problem. The challenge, according to Station scientists, is not one of preventing any human-induced change but rather one of deciding how much change will be allowed to occur, where it can occur, and how to control it. The LAC system is a nine-step process that quantitatively defines the amount of change to be allowed, identifies appropriate management actions needed to prevent further change, and establishes procedures for monitoring and evaluating management performance.



The limits of acceptable change (LAC) system is a nine-step process that helps managers solve the wilderness carrying capacity problem.



Unless wilderness managers grasp changing trends in the recreational use of wilderness, their efforts could be misdirected and inefficient. Managers need information on current conditions as well as dynamics of change in the use of wilderness areas.

Unfortunately, trends in wilderness use and user characteristics over the last decade have been the subject of much speculation but almost no research. Therefore, Intermountain Station scientists repeated a survey of visitors to the three-area, 1.5 million-acre Bob Marshall Wilderness complex. Questionnaires distributed to wilderness visitors in 1982 were basically identical to those used to study visitors to the same area in 1970.

The study identifies changes in user attitudes that provide management a chance to catch up with use-related problems, because many trends suggest some slowing of the future rate of growth of wilderness use and lower impact per party. However, the study also revealed that new problems are emerging, particularly growing dissatisfaction with trail conditions and increasing objections by hikers to the use of horses on the trails. Complaints about trails were six times as common in 1982 as in 1970. Visitors questioned in 1982 were opposed to facilities and more supportive of actions to preserve natural ecosystems.



A survey of users of the Bob Marshall Wilderness Complex revealed growing dissatisfaction over the condition of trails.

How Many Trees Should There Be in a Park?

Trees in urban parks are vulnerable to stress, disease, and insect attack. Many park managers are now planting "new" trees in anticipation of the decline and death of old trees. To be successful in maintaining the attractiveness of the park, managers need guidance about how many trees per acre look most attractive to park users.



The North Central Station and the Morton Arboretum cooperated in studying people's evaluations of various tree densities in two parks in the Chicago suburbs. Groups of people viewed and rated color slides depicting different tree densities. Most raters preferred tree densities of 50 to 65 trees per acre. A group of staff and volunteers at the Morton Arboretum, however, preferred somewhat higher tree densities of around 75 trees per acre.



This information can be used to guide tree replacement efforts by managers of parks where the species and size distributions of trees are similar to the parks photographed for this research. The Morton Arboretum is now cooperating with two Chicago-area park districts to implement these results in park reforestation programs to maintain attractive park landscapes for future users.



The middle photo was identified by viewers as having about the right number of trees for a park; the left photo was rated by viewers as having too few trees and the right, too many.

The emissions of nitrogen oxides in the South Coast Air Basin in southern California are among the largest in the Nation. Within the urbanized Los Angeles basin, 330 kilograms of nitrogen per hectare are released into the atmosphere annually. Recent research by the Pacific Southwest Station has identified these acid-forming emissions as a major source of acidic deposition and nitrate water pollution in nearby mountain watersheds. These areas provide a major source of drinking water, wildlife habitat, and recreation for metropolitan Los Angeles. Streamwater nitrate concentrations in watersheds subject to chronic air pollution are two to three orders of magnitude greater than those in chaparral regions outside the South Coast Air Basin.

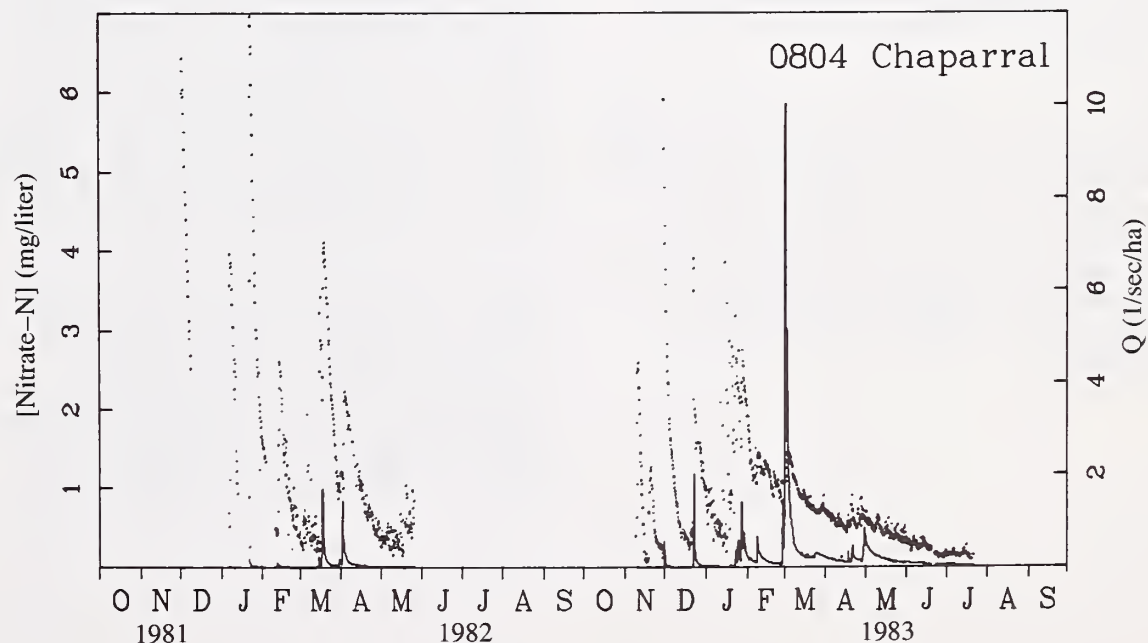
Station scientists found that nitrogen flux through the chaparral canopy was at record levels and especially elevated after smog episodes. The nitrate in throughfall apparently was derived largely from dry deposition on canopy surfaces. The nitrate water pollution problem has also been linked with vegetation management and the periodic occurrence of severe

wildfires that mobilize accumulated nitrogen compounds. Prescribed burning has been suggested as a means of managing long-term watershed nitrate loss.

Research in cooperation with the Association of Local Water Districts, eastern Los Angeles County, is continuing on the mechanisms underlying the deposition and biological processing of atmospheric nitrogen. An interagency program has

been developed to examine directly the role of severe fire in existing ground-water nitrate pollution.

Concentrations of NO_3 responded markedly to changes in stream discharge with the highest peaks occurring during early season storms. Concentrations fell rapidly following early storms but remained elevated for an extended period after large storms that saturated the soil profile.



Acid rain is a serious threat to forests, lakes, and streams in North America. The chemicals associated with high acidity—sulfates and nitrates—occur naturally and as emissions from the burning of fossil fuels such as coal, oil, and natural gas. Scientists at the North Central Forest Experiment Station have developed a method for estimating in North American precipitation how much sulfate and nitrate is natural and how much is emission related. This is an important step in evaluating the environmental benefits of emission controls.

These same scientists have found that emission-related sulfates and nitrates are linked to acidification of 5 to 10 percent of the clear-water lakes in northeast Wisconsin and Upper Michigan. Also, they can now estimate the number of lakes that will be affected if emissions increase or decrease.

Forest Service watershed scientists at the Northeastern Station have identified the soil properties that control the acid-neutralizing capacity of watersheds and have demonstrated that the ability of some soils to neutralize acids is very limited. In the worst-case situation, it would take just 30 years to increase soil acidity 10 times, given the acidity of today's rain.

At the Southeast Forest Experiment Station, scientists have shown that biological processes in watershed soils are important in delaying soil acidification. Specifically, they note that various organisms, including plants and animals, can retain sulfate rather than letting it move out of the soil. If unchecked, this movement will cause soil acidification.

Changes in watershed soils not only affect streams and lakes but also adversely affect tree growth. A tree-ring study of red spruce has documented a recent decline in growth that corresponds to increased emissions during the past 20 years.



● • GENERAL LOCATION OF LAKES SAMPLED IN EACH OF THE SEVEN NATIONAL FORESTS IN MINNESOTA, WISCONSIN, AND MICHIGAN

+ • HADP WET DEPOSITION COLLECTION STATION

Wet sulfate deposition (kg/ha/yr in blocks above) emitted from the burning of fossil fuels or copper smelting is low in central Minnesota and moderately high in Michigan. The impact on lakes, however, is greatest in northern Wisconsin and Michigan's Upper Peninsula, where 14 percent of the clearwater lakes on National Forests are already acid (lake pH values from 5.6 to 4.0). It is estimated that 3 percent have always been acid because they had little or no buffering capacity, and background levels of sulfate (nonemission) were high enough to acidify them.



Background



Emissions

Total wet sulfate deposition (kg/ha) in the United States and Canada has been partitioned into background and emission-related amounts. Background amounts, associated with individual storms above pH 4.9, are derived from sea salts, soil salts, and other natural landscape emissions that cannot be controlled by reducing anthropogenic emissions. Emission sulfates result from the burning of fossil fuels and copper smelting and are the only portion of wet sulfate deposition that can be changed.



Insects and Disease

Oak Sawtimber Losses in Stands Defoliated by Gypsy Moth

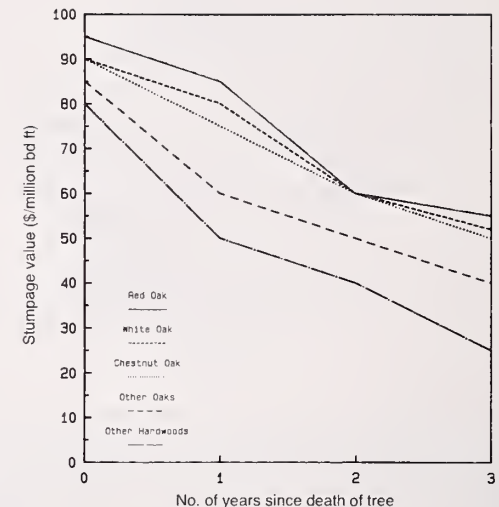
Timber buyers are biased against the purchase of dead trees. In the case of oak, at least some of their caution is justified because trees dead more than 2 years may be riddled with galleries of the oak timberworm, greatly reducing the value of products produced from this timber. As the gypsy moth swept across central Pennsylvania in 1978-82, scientists at the Northeastern Station began a study to estimate the impact of the pest on the oak resource.

Plots were established in 39 salvage sale areas on public and privately owned lands through the outbreak zone. Oak volume and value estimates were obtained from salvage sale records and from a series of prism point samples collected in 1983 and 1984. The volume of dead oak ranged from 3,500 to 11,000 board feet per acre, with values of the dead timber ranging from a low of \$281 to a high of \$914 per acre. Individual trees averaged 246 board feet.

Results of this study provide not only impact and economic data that will aid land managers in making better decisions on gypsy moth control but also valuable guidelines on the profitability and timing of salvage of dead sawtimber.



After high-quality sawtimber trees die following gypsy moth defoliation, they are attacked by wood-boring insects and decay organisms. These organisms cause the tree to deteriorate over a period of several years. Such trees may be suitable to make a variety of wood products for up to 4 years following death, but stumpage values decline rapidly.



Average stumpage values for living hardwoods and for trees that have been dead from 1 to 3 years.

Production of disease-resistant seed in western white pine seed orchards has recently been severely reduced because of periodic infestations of pine cone beetles, coneworms, and cone moths. Experiments were conducted in Sandpoint, ID, in 1981 and Moscow, ID, in 1984 to evaluate single and multiple applications of two insecticides—permethrin and fenvalerate—for protection of cones of blister rust-resistant western white pine. Concurrently, techniques were developed to monitor these pests to project damage and to time insecticide treatments.

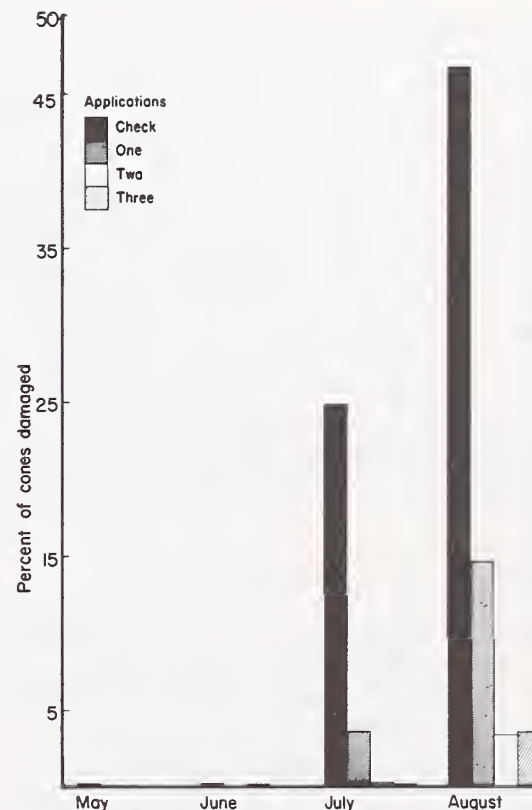
The two insecticides were chosen on the basis of human safety and efficacy against the key pests. Because timing of treatments is critical to protecting cone crops, insect activity is monitored throughout the orchards. Treatment began 1 day after the first insects emerged. In Sandpoint, where cone beetles completely killed the cones, cone losses ranged from 76 percent on untreated trees to 2 percent on trees receiving the double application of permethrin. At Moscow, where coneworms infested 47 percent of the cones on untreated trees, double applications of fenvalerate increased average seed yield from 31 to 56 seeds per cone.

The pine cone beetle was the only insect of concern in the Sandpoint Seed Orchard. This insect has destroyed up to 75 percent of the cone crop. A single application of 0.03-percent permethrin significantly reduced cone losses when compared to no treatment. Two applications of 0.12-percent permethrin nearly eliminated cone losses.

All insecticide treatments had a positive cost/benefit ratio. However, 0.06-percent permethrin applied once was the most cost effective.

Coneworms were the only insects to cause noticeable damage in the Moscow Seed Orchard. This insect reduced seed yield by about 44 percent. Two applications of 0.025-percent fenvalerate, once in May and once in June, significantly increased seed yield. A third application in July was apparently unnecessary.

Research continues to assess impact of all insects and to develop predictive monitoring systems. The goal of this research is to develop pest-management techniques that reduce, or even eliminate, the use of pesticides yet optimize production of this valuable seed, which is worth about \$2,000 per pound.



Summary Publications Highlight IPM Program Accomplishments

Summarizing, packaging, and disseminating new or improved technology concerned with bark beetles and diseases affecting southern pines is the payoff for accelerated pest management research, development, and application programs. The IPM Program (Integrated Pest Management Research, Development, and Applications Program for Bark Beetles of Southern Pines) has completed a series of summary publications that present information in a variety of formats that should be of interest to researchers, pest management specialists, and foresters. These include the following:

USDA Series Publications

AH 597 Anderson, R. L.; Mistretta, P. A. Management strategies for reducing losses caused by fusiform rust, annosus root rot, and littleleaf disease. 1982. (Reprinted 1984). 30 p.

*TFS Circ. 267 Billings, R. F.; Ward, J. G. D. How to conduct a southern pine beetle detection survey. 1984. 19 p.

AH 634 Thatcher, R. C.; Conner, M. D. Identification and biology of southern pine bark beetles. 1985. 14 p.

AH 641 Goyer, R. A.; Lenhard, G. J.; Nebeker, T. E.; Schmitt, J. J. Distinguishing immatures of insect associates of southern pine bark beetles. 1985.

AH 645 Mason, G. N.; Lorio, P. L.; Belanger, R. P.; Nettleton, W. A. Rating the susceptibility of stands to southern pine beetle attack. 1985. 31 p.

AH 648 Patterson, D. W. SAMTAM: a guide to sawmill profitability for green and beetle-killed timber. 1985. 31 p.

AH 649 Belanger, R. P.; Hedden, R. L.; Tainter, F. H. Managing Piedmont forests to reduce losses due to bark beetle-littleleaf disease complex. 1985. 19 p.

AH 650 Thatcher, R. C.; Mason, G. N.; Hertel, G. D. Integrated pest management in southern pine forests. 1986. 38 p.

Forest Service Publications

TB 1703 Nebeker, T. E.; Hodges, J. D.; Karr, B. L.; Moehring, D. M. Thinning practices in southern pines—with pest management recommendations. 1985. 36 p.

GTR WO-47 Woodson, G. Utilization of beetle-killed southern pine. 1985. 27 p.

GTR SO-56 Branham, S. J.; Thatcher, R. C., eds. Proceedings, Integrated pest management research symposium; 1985 April 15-18; Asheville, NC. 1985. 385 p.

GTR SE-34 Hertel, G. D.; Branham, S. J. Swain, K. M., Sr. Technology transfer in integrated forest pest management in the South. 1985. 77 p.

AIB 491 Branham, S. J.; Thatcher, R. C.; Mason, G. N.; Hertel, G. D. Integrated pest management in the South—highlights of a 5-year program. 1985. 19 p.

*Cooperator Publication

Additional information is available in the form of slide tapes from SOUTHFORNET at the University of Georgia, Athens, GA; and in a series of one-page fact sheets from the USDA Forest Service, Southern Region, Atlanta, GA.

Biological Control of the Larch Casebearer—A Success

At one time, the larch casebearer, an introduced pest, caused severe defoliation and growth loss of the western larch, estimated at 142 million board feet per year in the Western United States and Canada. The commercial management of this valuable timber tree was threatened.

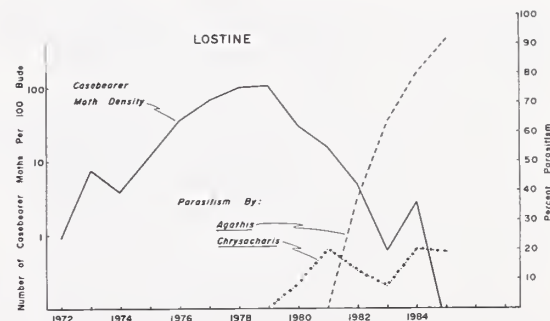
A solution was found by scientists at the Pacific Northwest Station, working in cooperation with Federal and State forest managers and private industry. The solution involved introducing exotic insect parasites that would reduce and permanently maintain casebearer populations at lower levels.

Beginning in 1960 and extending into the 1970's, seven species of parasites from Europe and Japan were imported and released into western larch forests. Two species, *Agathis pumila* and *Chrysocharis laricinellae*, became established and subsequently spread naturally or were manually transported throughout most of the infested area. Parasite populations have increased dramatically. Prior to the project, casebearer populations averaged about one per bud; now in many places there is less than one for every hundred buds—a density that causes no measurable damage.

The successful biological control of the larch casebearer will help to keep down prices for lumber, plywood, poles and other wood products made from larch. In addition to monetary benefits, watershed, recreational, and esthetic values are enhanced—all without the use of potentially hazardous pesticides.



The European parasite *Chrysocharis laricinellae* lays its egg into a large larva of the larch casebearer. The brown casebearer larva protrudes from its "case," which is fashioned from a section of hollowed needle.



After becoming established at this site about 1971, the casebearer population built up to over 100 for every 100 buds—a density that caused severe defoliation by 1978.

Predicting Loss From Fusiform Rust in Southern Pine Plantations

Fusiform rust is the most destructive agent yet encountered in southern pine plantations. The disease infects young plantations, causing galls to form on the branches and main stems of infected trees. Trees with stem galls often die, and those that survive usually are not as merchantable as noninfected trees.

In order to effectively manage rust-infected plantations, forest managers need an early assessment of the probable impact of the disease on future yields. Unfortunately, impact assessments are difficult because they depend upon complex interactions of many factors, such as site quality, the number of surviving trees per

acre, the proportion of stems infected, plantation age, and prospective utilization.

Forest scientists at the Southern Station, in cooperation with university and industry scientists, are solving this problem. The mathematical models they have developed can effectively integrate the various factors affecting future yields in infected plantations and provide realistic predictions of future yields. Originally, the models required large computers to carry out the complex computations, but recent advances in microcomputer technology have allowed the conversion of the system to smaller computers.

A microcomputer version of the yield-prediction system is now available for unthinned slash pine plantations. Systems are in the works for thinned slash pine and thinned and unthinned loblolly pine plantations. The system was primarily designed to provide forest managers with a simple, accurate method for early assessment of fusiform rust impact on future yields. The manager supplies basic input, and the system projects future yields for many different management options. The program also can combine the yield predictions with economic data, allowing the manager to make decisions that will minimize the economic impact of the disease.

Commercial Crop of Rust-Resistant Seeds

Owners of small forest tracts in Georgia soon will be able to plant loblolly and slash pine seedlings that are resistant to fusiform rust. That disease can decimate young pine plantations in central and southern Georgia and Alabama, killing or deforming almost all the trees in some plantings. The resistant seedlings that promise to cut these losses are the results of a cooperative effort by the Georgia Forestry Commission and the Forest Service's Southeastern Station.

The Forestry Commission provided the land and the labor, and the Station provided the expertise in pathology and genetics needed to establish a rust-resistant seed orchard. In 1984, the first commercial crop of seeds was harvested from the orchard. Some 70 pounds of seed were collected, which should provide over 300,000 seedlings for the 1985-86 planting season. Over the next few years, orchard production will increase dramatically.

Preliminary tests show that use of the resistant seedlings will reduce rust incidence by 40 percent in loblolly and 50 percent in slash pine. This level of resistance is the best produced to date in an orchard of commercial scale. The Georgia Forestry Commission, therefore, is sharing the genetic material with forest industries, which are trying to improve the resistance of material produced in their seed orchards.



The first commercial crop of seed from the fusiform rust-resistant seed orchard developed cooperatively by the Georgia Forestry Commission and the USDA Forest Service was harvested in the fall of 1984. Plastic netting is spread under the trees (left) to collect the seed as they are released from the cones (right). Over 70 pounds of seed were collected; they produced approximately 300,000 seedlings for sale to small landowners in areas with high rust hazard.



Nitrogen-Fixing Bacteria Are Associated With Tree Mycorrhizae

Growth of temperate forests is often limited by nitrogen deficiency. In the Douglas-fir region, however, a nitrogen-fixing system of potentially great value has been discovered. Researchers at the Pacific Northwest Station have found bacteria associated with the root-colonizing mycorrhizal fungi that trees need to absorb nutrients from the soil. The bacteria do not form nitrogen-fixing nodules as is the case with legumes. Instead, they produce the nitrogen-fixing enzyme only in the presence of the fungus and often die if the fungus is absent.

The nitrogen-fixing bacteria were first found in the fruiting bodies of

truffles, which are common mycorrhizal associates of Douglas-fir. For their spore dispersal, truffles must be dug up and eaten by animals such as the northern flying squirrel, the California redbacked vole, or the deer mouse. The spores pass unharmed through the animal's digestive tract and are defecated as inoculum "packets," from which spores are washed by rain into the soil to the tree roots. The nitrogen-fixing bacteria also survive passage through the animal and are active along with the spores. The bacteria occur on the fungal strands in the soil and in the tree mycorrhizae, where nitrogen-fixing activity occurs. The nitrogen-fixing bacteria appear to be

constant companions with the mycorrhizal fungi throughout their life cycle.

The nitrogen fixation rates of these bacteria in individual fungi and mycorrhizae appear to be low, but in the aggregate and over time they could be important nitrogen sources for tree growth. Now that the bacteria have been discovered, scientists can learn how they function and then develop management practices for enhancing their activity. The bacteria could also be inoculated along with mycorrhizal fungi into nursery beds or potting mixes in container nurseries to improve tree growth.



A northern flying squirrel searches for truffles in a white spruce forest near Fairbanks, AK: (left) The squirrel smells a truffle, (center) digs about 2 inches down to find the subterranean fungus, and (right) enjoys a real feast.



Micromorphology of Wood Degradation by Brown-Rot Fungi

Due to increased pressure to withdraw or restrict many of the currently used wood preservatives, scientists at the Forest Products Laboratory (FPL) are actively seeking new, environmentally acceptable methods of wood protection. Critical to developing these new methods, however, is a thorough understanding of the manner in which wood-decay fungi deteriorate wood.

Brown-rot fungi are an important group of wood-decay fungi that utilize primarily cellulose and hemicellulose of wood. Understanding how they degrade these cell-wall materials has frustrated researchers for years. Using microscopic techniques, FPL scientists identified the sites of attack and morphological changes that occur during degradation of wood by brown-rot fungi. Previous to this study, these fungi were thought to have very little effect on lignin. With the aid of a lignin-specific stain, however, it was demonstrated that the fungi strongly disrupt the structural integrity of lignin in the cell wall. In some areas it appears completely removed. Furthermore, a

sheath of gellike material covering the fungi was implicated as the site or transmitter (or both) for cell-wall-degrading agents produced by the fungi. The degrading agent(s) penetrate deep into the cell wall causing preferential degradation of cell constituents in the inner (S_2) wall. This type of attack on wood differs from that of other organisms and is most likely initiated by a small nonenzymatic agent.

Discovery of the involvement of hyphal sheaths in wood degradation and the changes that occur to cell-wall constituents during degradation will speed the search for feasible, nontoxic ways to control wood-decay fungi.



A plant pathologist at the Forest Products Laboratory uses a video camera attached to a microscope to study changes in wood microstructure through progressive stages of fungal degradation.



Fire and Atmospheric Sciences

Determining the Economic Costs of Fire-Management Programs

Researchers at the Fire Planning and Economics Unit at the Pacific Southwest Station have developed a procedure for estimating the economic or "opportunity costs" of fire-management programs. The procedure aggregates both direct and indirect costs for standardized fire-management inputs and converts these to per-hour costs for various levels of deployment. The procedure is a major improvement over earlier attempts at cost estimation in two ways: it incorporates costs that are not typically included in accounting data, and it is flexible enough to be applied by different fire-control organizations in their fire-planning activities. The procedure is computerized and has been used to evaluate costs in four Forest Service regions and three State fire-control agencies.

The cost procedure groups costs into five basic fire-management activities: prevention, detection, fuel treatment, initial attack, and suppression. So far, the procedure has been applied only to initial

attack and suppression costs. A Forest Service task force is now exploring alternatives on how to incorporate this cost procedure into the National Fire Management Analysis System.

Conclusions from the study are: (1) nationwide cost averaging across broad geographical areas and between different levels of deployment status masks important differences; (2) standing fire organizations are expensive, and the suppression cost per acre burned increases substantially as the size of the suppression organization rises; (3) the travel cost to fires is high; and (4) during dispatch planning procedures, attention should be given to cost increments beyond availability status.

The cost compilation procedure has been computerized, and a questionnaire has been developed as a format for data collection within the organization. Data collection and analysis can be achieved in one person-week of work. The cost procedure can be used in long-term planning or in guiding short-term operational decisions.



Costs of Fire Suppression Forces Based On Cost-Aggregation Approach

Armando González-Cabán Charles W. McKetta Thomas J. Mills

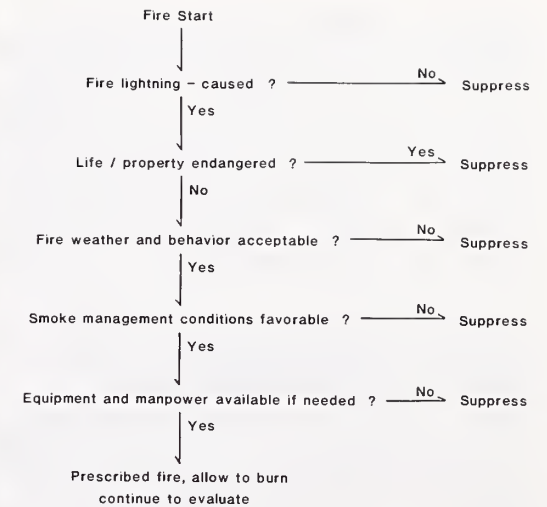


In forests managed for wilderness and natural-area objectives, managers face difficult decisions on how to cope with fire. Should managers allow natural ignitions to burn? Should they suppress them? Or should they combine suppression with the use of "prescribed" fire to simulate the natural effects of lightning-caused fires?

To promote an understanding of wilderness fire-management issues and techniques, the Intermountain Station developed a planning guide and sponsored a symposium on wilderness fire management. The symposium, heralded as a benchmark in this subject area, promulgated timely new information and provided a forum for discussion of controversial wilderness fire-management issues. As a result, the Forest Service changed its policy to allow deliberately scheduled ignitions in wilderness areas where fire-management objectives cannot otherwise be met.



Research is providing answers to the dilemma of how to manage fire in wilderness.



A planning framework provides managers with a methodology for considering actions with fire in wilderness.

Personnel engaged in wildfire suppression and the use of prescribed fire are always looking for new ways to construct firelines. Intermountain Station scientists designed a study to determine physical characteristics of firelines constructed with linear explosives, as a possible method that would save time and money.

The results of the study show that blasting firelines can be a useful tool in fireline construction. Initial results of field experiments using seven-strand fireline explosive cord and a water-gel explosive to produce blasted fireline suggest that fireline explosives can be more efficient than hand labor or bulldozer. In the future, explosives will occupy an important place in the array of available control techniques for both prescribed fires and wildfires.



Before (left) and after (right) views of a fireline cleared with explosives. Intermountain Station studies have shown that explosives are a cost-effective way to construct firelines.

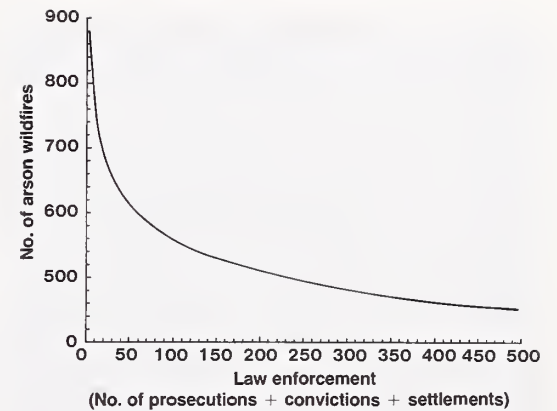
Law Enforcement Reduces Arson Wildfires

Law enforcement is an important part of forest fire prevention. It is used to prevent and reduce violations of wildfire laws in our Nation's forests, thereby protecting human life and preserving our valuable forest resources. Scientists at the North Central Station have shown quantitatively, for the first time, that law enforcement reduces arson wildfires. This is particularly significant because arson is the leading cause of wildfires in the United States today.

To demonstrate the effects of law enforcement activities on wildfire occurrence, researchers first had to screen out the effects of other factors that also influence fire incidence, such as weather, population density, and length of fire season. When these were removed from the picture, scientists found that arson fires in East decreased as the number of prosecutions, convictions, and settlements increased. They showed that a minimum amount of law enforcement effort greatly reduced the number of arson wildfires but that additional enforcement yielded a smaller reduction. Researchers concluded that States vigorously enforcing laws against arsonists would probably realize a small reduction in

arson fires in response to increased enforcement efforts. On the other hand, States with little or no law enforcement may initially realize a large reduction in arson fires by increasing their efforts.

Researchers plan to extend the work by incorporating cost and value criteria, which would, in turn, allow managers to determine the economically efficient level of arson law enforcement. Results of this recently published research are applicable throughout most of the eastern half of the country.



The relation between arson wildfires in the Eastern United States and law enforcement.

Studies of the behavior and effects of forest fires have been hampered by the changing nature of the beast. A single fire may burn with great intensity in some places and much less intensity in others. By the time observers figure out precisely what the fire is doing, it is doing something else. The answer, of course, is to have a continuous record of the fire's behavior through time and space, and movie cameras have long been used for this purpose. The film had to be developed and analyzed, so the system was slow and expensive and produced nothing of value to the people who were trying to contain the fire.

Fire researchers at the Southeastern Station have put together a system using video cassette recorders and computers that record and analyze fire much more quickly. Data and analyses that once took a week or more to obtain can now be had in a matter of minutes. The system was developed primarily for research purposes, but it holds much promise for use in fire management.

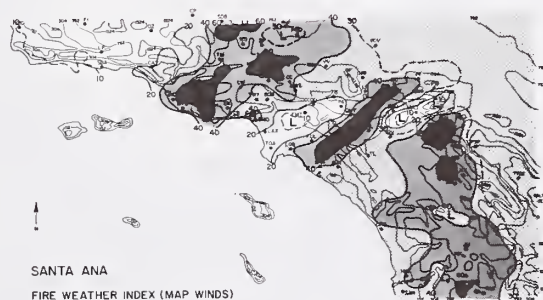


A scientist at the Southeastern Station uses the fire-behavior image analysis system.

In the past, site selection for fire weather stations was limited to locations where an observer was available. With the advent of remote automatic weather stations (RAWS), fire weather measurements could be taken where and as often as needed and transmitted via satellite—without manual intervention. However, no accepted method existed for designing fire weather networks.

Research at the Pacific Southwest Station has yielded a means of determining the number and locations of fire weather stations appropriate for a given management prescription. The manager's need for weather information is translated into quantitative criteria that a computer uses to select optimum locations for weather stations. The method was used to devise a fire weather network plan for southern California, where weather analysis is complicated by mountainous terrain and by the interplay between land and sea. Computer models were used to represent fire weather problems induced by Santa Ana and heat-wave conditions, such as those that ravaged southern California in the summer of 1985. The design process takes existing weather stations into account, to avoid unwanted duplication of data.

The southern California network plan encompasses four National Forests in the Pacific Southwest Region and various State and local jurisdictions. The design method is being considered further for planning hydrologic networks and meteorological experiments.



A fire weather network plan for southern California was partially determined by weather sampling problems evident in a case study of Santa Ana conditions. The darker shading denotes zones with higher fire potential.



Remote automatic weather stations make it possible to sample weather virtually anywhere. Data are transmitted to a geostationary satellite through the antenna mounted on the frame. (Photo courtesy of H. Fallek.)

Crown Scorching Retards Growth of Southern Pines

Because of their well-insulated bark, southern pines larger than saplings are widely renowned for their resistance to fire damage. This resistance permits foresters to favor pines over their competitors by setting low-intensity, prescribed fires in the understories of maturing pine stands. Occasionally, however, these fires get hotter than expected and portions of the pine crowns are scorched.

Since the pines usually recover, most foresters have assumed that scorching is not harmful. However, results of recent studies by Southeastern Station fire scientists show otherwise. Scorching retards growth for several years after it occurs, and the more scorching, the greater the growth reduction.



Severe crown scorch retards growth of maturing slash pine. But by age 4, bark thickness and cross-sectional area are sufficient to protect the lower boles of southern pines from lethal fire damage.

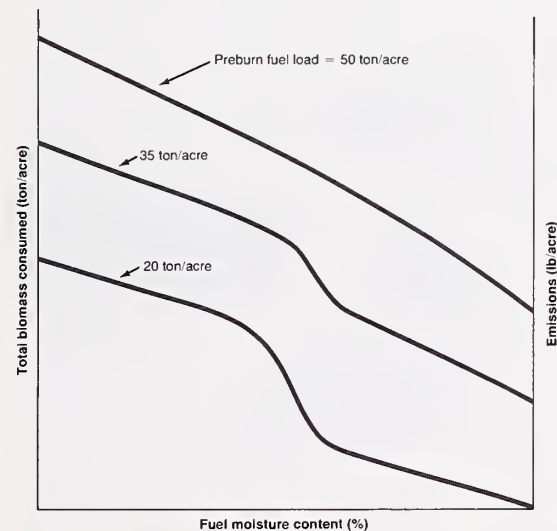
Air Pollution Reduced From Slash Burning

Reducing emissions from prescribed forest burning is an important goal in the Pacific Northwest to meet stringent-air quality standards. A cooperative effort of forest researchers at the Pacific Northwest Station and forest land managers in the region has had a major impact on emissions. Even though the area treated by prescribed burning has increased in the last 10 years, emissions have decreased by 30 percent!

Two major developments from research are contributing to this effort: (1) new guidelines for reducing emissions, and (2) a new emissions inventory system that measures progress in reducing emissions. The guidelines include higher utilization standards (which means less material is burned); scheduling of burning during weather conditions favorable to dissipation of the smoke; and mass ignition, which makes for a hotter fire that produces less smoke.

The emissions inventory system utilizes site-specific data and meteorological records for computing the quantity of fuel consumed and emissions produced from all slash burns for each day. National Forests in the Pacific Northwest use the

system to report annual emission-reduction progress to State air-quality agencies. The State agencies use the system to compile daily slash-burn emission inventories that explain the forestry contribution to regional air pollution problems. State forestry offices will soon use the system to predict and manage smoke from State Forests and private forest lands on a daily basis.



Biomass consumption and emissions over a range of woody fuel moisture content.



Prescribed broadcast burn of logging slash with tower and cable system used to support emissions sampling equipment over fire.



Genetic Variation in Western White Pine

To find out more about how western white pine adapts to different environments in the northern Rockies, scientists at the Intermountain Station compared the characteristics of populations from everywhere the species grows. Researchers studied western white pine's growth potential, morphology, freezing tolerance, and the periodicity of shoot elongation. The diagram depicts genetic differentiation by contours of relatively equal performance. The zero contour represents trees with the lowest growth potential but highest hardiness. According to this figure, north coastal and inland populations of western white pine form an amorphous group with little or no genetic differentiation. Individual trees tend to have high growth potential but low cold hardiness. In contrast, populations of trees from the Sierra Nevada tend to have low growth potential and high cold hardiness. Trees from areas between these two groups are arranged along gradations of growth potential and cold hardiness.

These results apply directly to forest management. Seed transfer guidelines, seed zones, and breeding units are intended to limit poor adaptation of planted trees. But since adaptive differentiation in the northern Rockies cannot be demonstrated, seed transfer can be unlimited within the ecological boundaries of western white pine. This unexpected result delights silviculturists and tree breeders who deal with white pine. Now programs for this species may avoid the costs of maintaining a large number of small seed inventories for reforestation.



Scientists discovered that western white pines exhibit genetic similarities along geographic contours.

Estimating Cold Hardiness of Seedlings by Differential Thermal Analysis

Successful reforestation with planted tree seedlings requires high rates of transplant survival. One key to survival is the ability of newly transplanted seedlings to survive low temperature. This ability—called cold hardiness—develops at a different rate among different tree species, and even among seed sources of the same species. Production variables in the nursery also affect the hardening process. The problem is particularly critical in container-grown seedlings produced under controlled conditions in containerized greenhouse nurseries designed to achieve rapid growth.

Currently, there is no convenient method to determine when a particular lot of seedlings is hardy enough to survive. Whole-plant tests, where several seedlings are exposed to controlled freezing temperatures, are cumbersome and time consuming.

Scientists at the Rocky Mountain Station are applying a new technique—differential thermal analysis (DTA)—to get rapid, objective, and precise measures of cold hardiness. DTA is a method of monitoring temperature at which water freezes during a freeze-thaw cycle. Freezing points are marked by the rise in

temperature associated with the release of heat of fusion. The temperature at which supercooled intracellular water freezes closely matches the tissue's killing point. And it occurs at a progressively lower temperature as woody plants cold-harden.

A big advantage of DTA is that the technique is nondestructive. Only a few lateral buds are taken from sample seedlings.



Putting a seedling bud in an aluminum capsule for a 30-minute differential thermal analysis (DTA).

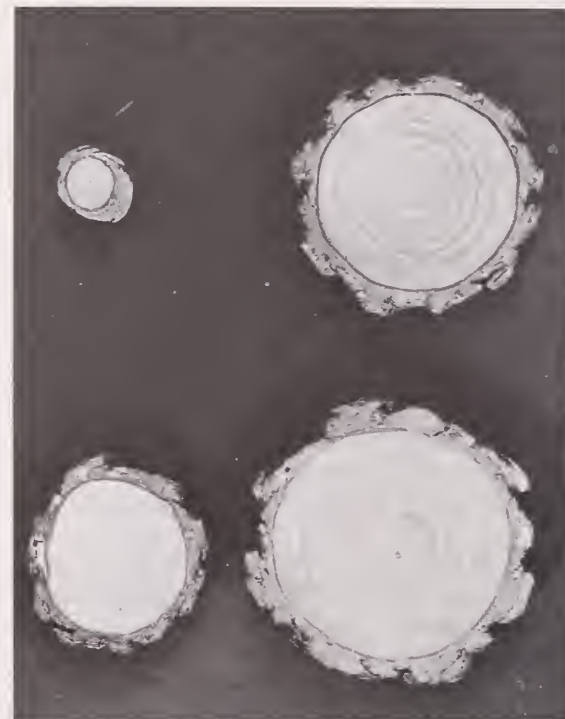


Conventional whole-seedling freezing tests take 2 weeks.

Millions of acres of potentially productive soil for pine culture on the coastal plain of the South are made unsuitable by poor drainage. For years, forest industry has made these areas productive by building artificial drainage systems and raised beds for pines to grow on. The results are satisfactory, but the costs are quite high. Soil scientists at the Southeastern Station have another approach that works almost as well and costs far less. They have had great success in substituting phosphorus applications for artificial drainage.

Loblolly pine, they find, requires more soil phosphorus on waterlogged than on well-drained soils. Applying phosphorus at the rate of 50 to 100 pounds per acre greatly increases growth of recently planted pine trees on wet sites that have not been drained. The trees then become acclimated to the wet conditions. As the trees grow, they take up and transpire more and more water, lowering the water table and effectively draining the site.

On some sites, phosphorus application alone stimulates growth about as much as drainage and bedding without fertilizer application. Growth is best when a site is drained, bedded, and fertilized, but that combination of treatments is very expensive.



Effects of phosphorus and drainage on 10-year growth of loblolly pine planted on a poorly drained soil in the southern coastal plain. No treatment (upper left), phosphorus alone (upper right), drainage alone (lower left), and phosphorus and drainage (lower right).

Lodgepole Pine: The Species and Its Management

A blanket of lodgepole pine forests covers millions of acres in the Western United States and Canada, and forest managers in both countries need state-of-the-art information on how to maximize its value. Lodgepole pine is the principal species on over 60 million acres in the two countries and accounts for 16 percent of the annual lumber harvest in the Mountain States of the United States and 20 and 40 percent in British Columbia and Alberta, respectively. And its worth extends beyond its economic importance in terms of timber to its influence on watershed, wildlife habitat, and scenic beauty.

To pass along new information about managing the lodgepole resource, Intermountain Station sponsored a major symposium on the subject with a published proceedings. Included are 38 papers with current information on the extent of fire relationships, regeneration and stand culture practices, growth and yield, harvesting and utilization practices, and a look at the future of lodgepole pine forestry. The collective update of new knowledge by Intermountain Station scientists and others makes it possible for forest managers in both countries to plan more effectively and

make more informed decisions on the management of this important forest type.



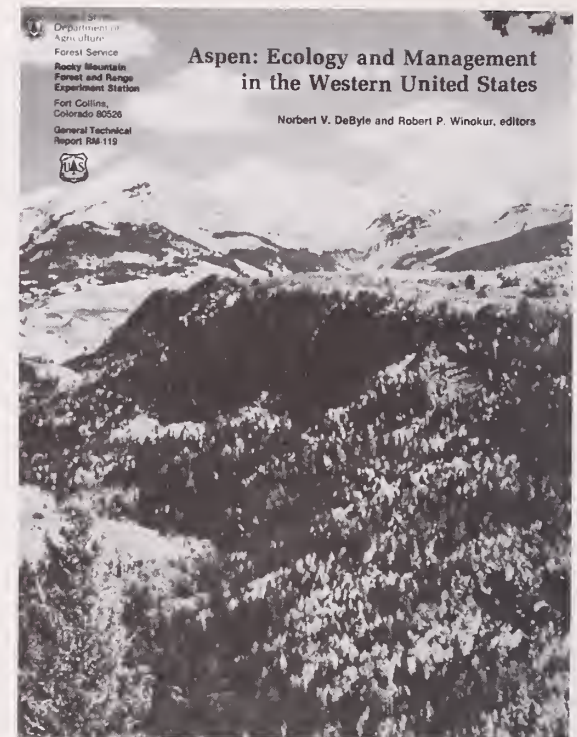
Lodgepole pine forests occupy millions of acres in the Western United States and Canada and represent an important resource for both Nations.

In the West, aspen forests are primarily valued for wildlife habitat, livestock forage, watershed protection, and esthetics and recreation. These uses seldom generate enough money to enable landowners to actively manage much of the aspen ecosystem. As a result, adequate measures have not been taken to ensure that this species, where it occurs as part of the natural forest succession, is retained where other resources benefit from its presence.

Aspen reproduces almost entirely from root suckers, rather than seeds. On many sites, therefore, aspen may not persist unless the stand is periodically rejuvenated by some event (e.g., fire) that initiates a new stand. Because of the decrease in severe fires resulting from modern forest-fire prevention and suppression practices, natural succession is replacing aspen with conifers or other vegetation types in seral stands.

So that managers can make responsible decisions on how best to manage and retain aspen in various situations, scientists with the Rocky Mountain and Intermountain Forest and Range Experiment Stations, and their cooperators, have written a major book. "Aspen: Ecology and Management in the Western United States," General Technical Report RM-119, is a 283-page summary of the status of our knowledge about aspen.

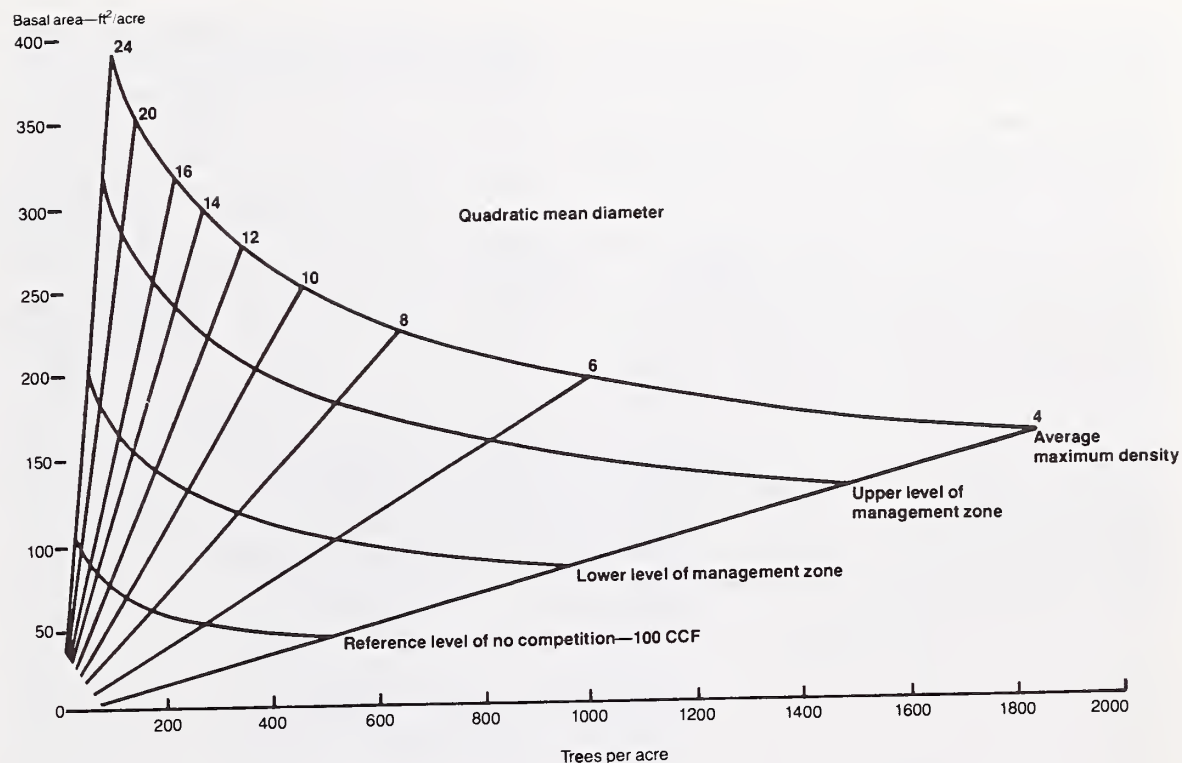
The book discusses the biology of aspen as a tree species, community relationships in the aspen ecosystem, environments, and factors affecting aspen forests. It also covers resources available, current and potential uses, and silvicultural and other approaches to managing aspen. The book is available for \$8.50 from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.



Forest Stands: Too Dense? Appropriately Stocked?

The National Forest Management Act of 1976 mandates that forested lands in the National Forest System be maintained with a degree of stocking designed to ensure the maximum benefits of multiple-use sustained-yield management. Yet for almost a decade, carrying out the law has been difficult because existing definitions and concepts of forest stocking were ambiguous. The 1985 publication of General Technical Report WO-44 resolved the ambiguities. In preparing the report, Northeastern Station scientists thoroughly examined current and historical theory and practice to establish a uniform approach for measuring relative stand density and expressing management guidelines as stocking levels. This approach will be used throughout the National Forest System.

Relative stand density, as defined in the new report, is the measurement of stand density relative to an established baseline, usually the average maximum basal area found in stands of the same species and size. Stocking is the range of relative densities designated optimum for a particular management objective.



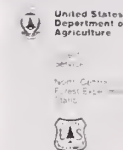
The Gingrich stocking guide, adopted by the National Forest System, displays basal area, the number of trees, and the quadratic mean diameter.

For half a century researchers in the Lake States have been learning how to manage northern hardwood forests. The job has been a complex one because so many different species of trees make up these forests.

Covering 10 million acres in the three Lake States alone, most northern hardwood forests have been cutover at least once. Second-growth stands have reached pole-size, but many of them are slow growing and of poor quality.

To help these forests achieve their economic and ecologic potential, silviculturists at the North Central Station gathered together all their past research on northern hardwoods.

Then, borrowing from years of experience in presenting this information live to practicing foresters, they wrote 48 notes that distill the complex research into clear, straightforward recommendations for the field forester. Covering all aspects of management, from insect and disease control to regeneration methods and wildlife openings, these "Northern Hardwood Notes" are offered for sale in looseleaf form by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. The collection will be supplemented and updated by the North Central Station as new research results come to light.



Northern Hardwood Notes



The upland oak timber type, which occupies nearly 109 million acres, is the largest in the United States. And currently this resource is producing timber at less than half its potential. Management is especially complicated because 82 percent of the acreage is in nonindustrial private ownerships. Scientists at the Northeastern Station developed a computer model called OAKSIM to enable managers to examine the effects of various stand treatments without actually performing them in real life.

OAKSIM "grows" individual trees and estimates their timber yields under different regimes feasible for managed stands of even-aged upland oak. Thinning is the silviculture practice with the greatest potential for increasing the growth and yield of such stands. The timing, intensity, and frequency of intermediate thinnings can be studied in detail with OAKSIM for a wide range of age, site, and stocking conditions.

The recently completed version of OAKSIM provides growth and yield information by species and size classes for projections up to 50 years in the future. Once quality and economics are added to OAKSIM,

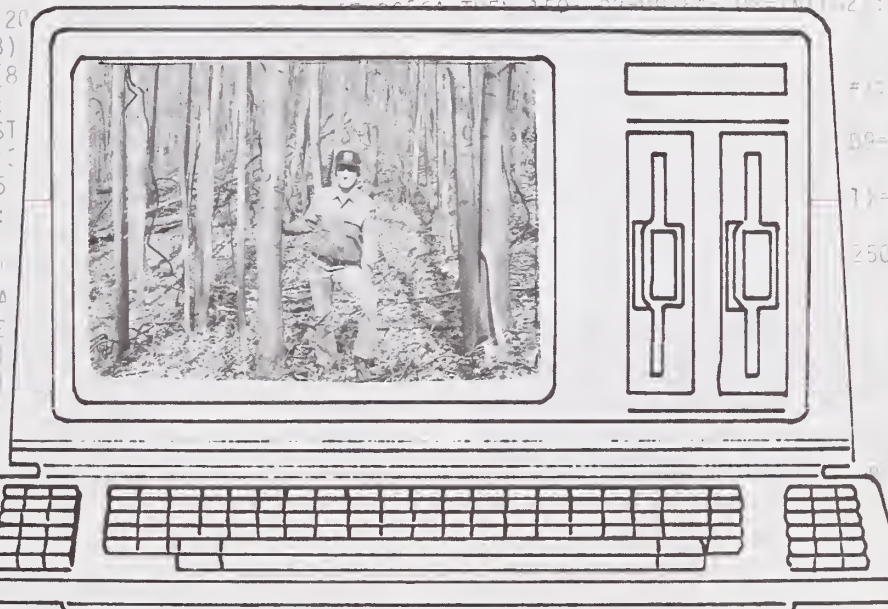
management guidelines will be developed by repeatedly running the simulator for various stand conditions and thinning strategies.

OAKSIM

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16,0): GOSUB '101(B3$): D1=ROUND(D2+X1,D1): GOSUB '200: GOSUB '130: RETURN
110 DEFFN'101(H2$): IF H2$="
=11: IF H2$="C" THEN X1=12: I
"THEN X1=15: RETURN
120 CONVERT H2$ TO X1: RETURN
130 DEFFN'190: GOSUB '20: PR
C): INPUT D1: IF D1[0 OR D1]255 THEN 130: GOSUB '200: GOSUB '150: RE
TURN
140 DEFFN'20
UND((D2-D3)
150 IF D9[8
160 D1=D9:
RT D1 TO ST
170 DEFFN'
(H1-H2)*16
180 H2=D9:
ETURN
190 DEFFN'
200 X1$="A
210 X1$="E
220 X1$="I
230 X1$="J
240 X1$="K
250 X1$="L
260 CONVE
270 DEF
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290 DE
300 IF
310 E
T TAB(4),A1$:
11:1$: A1$,H1$,H1$,H1$,H1$-A1: GOSUB '101: RETURN
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Transferring Genes From Bacteria into Pines—A Step Forward in Genetic Engineering of Forest Trees

Genetic engineering of forest trees, once thought to be a fanciful notion by traditional forest scientists, is rapidly coming closer to reality. The methods of gene splicing that promise to bring new products in medicine, industrial biochemistry, and agriculture also have significant potential in forestry. A major limitation in the genetic improvement in trees has been the long generation times of the important tree species. Genetic engineering has the potential to bypass the normal breeding process and to create improved combinations of genes in a single year that could take hundreds of years by the traditional process. A major requirement for the development of genetic engineering in forest trees is a way to introduce foreign genes into commercially important tree species.

A method for gene transfer has been developed by scientists of the Pacific Southwest Station, North Carolina State University, and Oregon State University. These scientists have

succeeded in the transfer of genetic information from a common bacterium into loblolly pine, the Nation's most widely planted forest tree. This is the first demonstration of gene transfer and function in a commercially important conifer. This result makes possible the transfer of genes derived from other plants or genes created in the laboratory into commercial tree species. The long-term goal of these studies is the genetic improvement of trees without the limitations of the long breeding cycles.

Certain species of soil bacteria, known as Agrobacterium, can transfer genes into the cells of many crop plants. When this transfer occurs, the genes behave as though they were a normal part of the plant's own hereditary material. The bacterium is, itself, a genetic engineer. By harnessing the natural ability of the bacterium, it is possible to place foreign genes into the bacterium, and to have it transfer those genes into



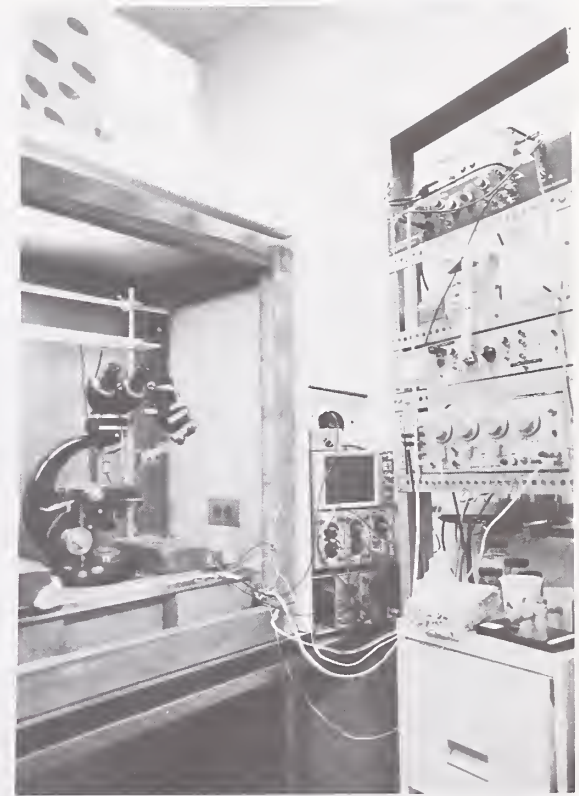
Crown gall induced on a loblolly pine seedling. Biochemical tests of the tissue from this gall show that bacterial genes are transferred and expressed in cells of loblolly pine. These results greatly extend the potential for genetic engineering in pines and other tree species.

the plant cells. The major advance that has been made this year is the application of this procedure to forest trees. It has been demonstrated that Agrobacterium can transfer genes into cells of loblolly pine and that the transferred genes can be expressed.

Agrobacterium is also known as the agent of crown gall disease. In the disease process, genes that have been transferred to the plant cells cause the formation of a gall, or plant tumor. Transfer of genes may take place without gall formation, and other factors such as wounding can induce galls. At the beginning of this work, crown gall was not known to infect pines. Many natural and laboratory strains of Agrobacterium were surveyed before some were found that produced galls in loblolly pine. To show that actual transfer of active genes had taken place, infected plants

were assayed for the presence of unusual chemicals called opines. Opines are unique in that they are not found in bacterial cells, nor are they found in uninfected plants. Opines are specifically found in plant cells that have been modified by the insertion of genes from Agrobacterium. Opines were detected in high levels in the infected loblolly pine tissue.

These results make possible many kinds of genetic experiments in pines that could not be done previously, because new genes can be inserted and studied without breeding trees for many generations. The next steps in this work will be the transfer and expression of commercially important genes into conifers and the regeneration of trees from genetically modified tissue. Experiments of this kind are now in progress.



A forest biotechnology laboratory for the direct transfer of genetic information into cultured cells of important forest trees such as loblolly pine, Douglas-fir, and sugar pine. In this lab, microprobes are used to carry novel genes into conifer cells, thus bypassing the normal breeding process.



Resource Economics

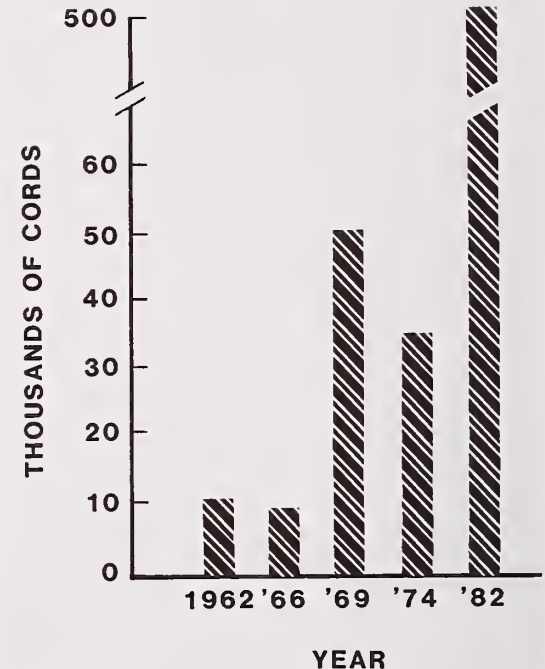
Fuelwood Dominates Colorado's Tree Harvest

In surveying the forest resource situation in Colorado, Intermountain Station scientists found that the use of fuelwood as an alternative energy source has increased dramatically.

The estimated 1982 fuelwood harvest in Colorado was 505,000 cords (40.4 million cubic feet), about double the harvest of industrial roundwood products such as sawlogs, houselogs, posts, and poles. It was the largest annual fuelwood harvest reported in Colorado in several decades and 470,000 cords more than reported for 1974.

Scientists found that standing live trees of timber species from forest land composed only 10 percent of this fuelwood harvest. The remainder comprised dead trees, nontimber tree species, and trees from nonforest land.

Commercial fuelwood operators reported harvesting only 18,000 cords, less than 4 percent of the total. However, nearly half their harvest was standing live timber trees from forest land. Wood cut by members of households for personal consumption totaled 486,000 cords, or 96 percent of the entire cut. Fifty-seven percent of the fuelwood harvest was from private land, 31 percent from National Forests, and the remainder from BLM, State, and nonforest lands.



Fuelwood consumption in Colorado has grown drastically since 1962.

State resource planners and forest-industry analysts depend on information from forest inventories in planning industrial development and resource management. But completion time for State forest surveys has increased lately due to the rising costs of performing inventory work. During the last 5 years, for example, the average period between successive resource inventories stretched from 10 to 14 years nationwide. In 1985, additional funding was budgeted for the Forest Inventory and Analysis Program; and the previous 10-year cycle has now been restored. The data collection phase of the Virginia inventory was accelerated from 20 months to 14 months, and a similar reduction was achieved during the Illinois and Indiana inventories.

Nationwide, the area of forest land covered during fiscal year 1985 increased 80 percent over 1984 because of the additional funding. Besides the States mentioned above, new inventory statistics will soon be available for southeast Alaska, Arizona, Delaware, Louisiana, Maryland, New Jersey, New Mexico, western Oregon, and Texas.



**Modeling Changes in the Acreage of Forest Land
Among Ownerships and Timber Cover Types in
the Southeast**

Much of the pine timber being harvested now in the South comes from timber stands that naturally seeded on abandoned farmland. In a continuing effort to improve methods of projecting forest land acreages, Forest Service scientists have developed a land-area projection model based on proxies for the relative economic returns that accrue to the two most important land uses—agriculture and forestry. The combination of that model with historical Forest Inventory and Analysis data in that region led to projections of a drop in forest land acreage of approximately 5 percent in

the Southeast between now and the year 2030. The forest industry share of that forest land base is projected to increase, as is the miscellaneous private class. The forest acreage held by farmers, on the other hand, is projected to drop from about 30 percent to less than 20 percent of the private forest acreage in the Southeast. The portion of forest land in planted pine stands is projected to increase from 15 to 25 percent of the private forest land; the portion in hardwood types is projected to remain about constant; the portion in natural pine stands was projected to decline.

Slope Stability Analysis and Resource Management Planning

Many areas in the northern Rocky Mountains are unstable, with a high potential for mass failure (landslide). Because road construction and timber harvesting can create critical situations, managers who plan activities on such sites must be able to identify critical slopes and select alternatives that avoid or stabilize these areas.

The Intermountain Station has developed analytical techniques that address the problem of planning on sensitive sites. Of great use to field-going personnel has been the development of computer programs that provide comprehensive slope stability analysis for use with hand-held programmable calculators.

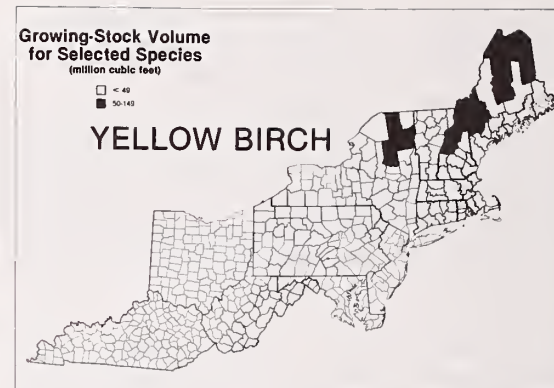


The use of adaptable field-going computer programs will help managers avoid or stabilize critical landslide areas during management activities.

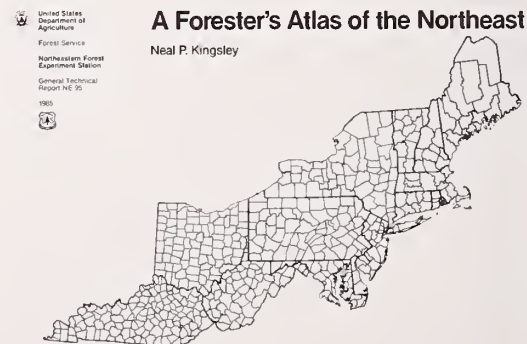
Of the 14 Northeastern States' 178 million acres of land, 57 percent is forested, though the degree of forestation and character of the forests vary greatly. Maine is 90 percent forested, for example, while less than 24 percent of Ohio's land is in forests. In the north, the forests consist of northern softwoods (white pine, hemlock, spruce, and fir) and northern hardwoods (maples, beech, and birches). In the south, the forests are primarily part of the great oak-hickory forest of the East-Central States.

This same 14-State region is home to more than 70 million people, nearly one-third of the Nation's population. The population of the region, like its forest land, is not evenly distributed. Northern Maine is sparsely populated, yet the nine most densely populated States in the Nation—New Jersey, Rhode Island, Massachusetts, Connecticut, Maryland, New York, Delaware, Pennsylvania, and Ohio—are all in this region.

Comprehensive inventories of the forest resources of the Northeast have been made, and these data have been analyzed. Yet little of this information has been displayed geographically. The purpose of "A Forester's Atlas of the Northeast" is to provide a cartographic display of forest resource information and of other related data in a handy reference form for foresters, regional planners, and analysts. The atlas contains information about land resource areas, physical subdivisions, soils, water resources, forest resources, climate, population, income, labor, transportation, and timber products output.



This map shows the growing-stock volume of yellow birch. Growing-stock volume is the net volume, in cubic feet, of live trees of commercially acceptable species and form that are at least 5.0 inches in diameter at breast height, outside bark of the central stem, or to the point where the central stem breaks into limbs.



"A Forester's Atlas of the Northeast" provides a cartographic display of forest resource information and other related data.

Identifying Errors in Bids for Silvicultural Services

To help the Forest Service determine whether or not money is being spent efficiently for timber management, researchers at the Southern Station developed a new way to examine transaction evidence. The first statistical procedure allows land managers to estimate what tree planting, site preparation, or herbicide application should cost before soliciting bids. The second procedure allows land managers to identify abnormally low bids on a particular contract immediately after the bids are opened. Taken together, these two techniques allow the Forest Service to avoid paying an abnormally high price for silvicultural services and also to identify abnormally low bids, where the probability of the bidder defaulting on the contract is high.

A notable advantage of these procedures is their ability to summarize information from contracts for a wide variety of services differing greatly in absolute cost. Previously, only subjective judgments regarding whether bids were too high or too low were possible. The statistical procedures were then adapted to examine transaction evidence from timber sales. In initial trials, the procedures successfully identified times when the stumpage market underwent structural change. The method shows promise for evaluating whether or not timber sale bids are competitive without having to conduct an appraisal or publish an "advertised rate" in the offer to sell stumpage.

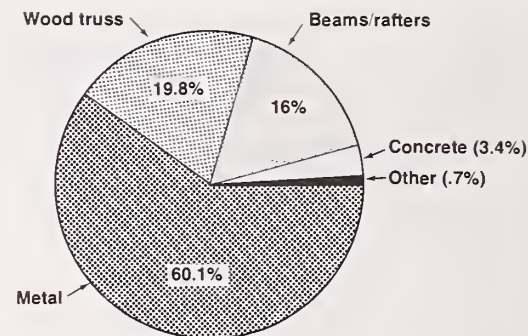
Construction of nonresidential buildings eats up a lot of dollars. In a typical year, 30 percent of all construction dollars are for nonresidential buildings as compared to about 36 percent for residential. Yet a recent study conducted by the Forest Products Laboratory and the American Plywood Association shows that residential buildings typically utilize five times as much wood as nonresidential structures. What factors keep wood from being used in nonresidential buildings?

One major reason many builders give is the restraining effect of building codes that favor noncombustible materials in the larger structures that characterize nonresidential buildings. Another reason is engineers' and architects' lack of familiarity with wood properties and designs. Whatever the reasons, the study shows a minority, although still substantial, position for wood in most segments of nonresidential building construction. For example, over 36 percent of all roofs are framed with wood. This is due in large part to the success of truss fabricators. In framing of exterior walls, wood construction held an 18-percent share, up from 14 percent reported in a 1969 study.

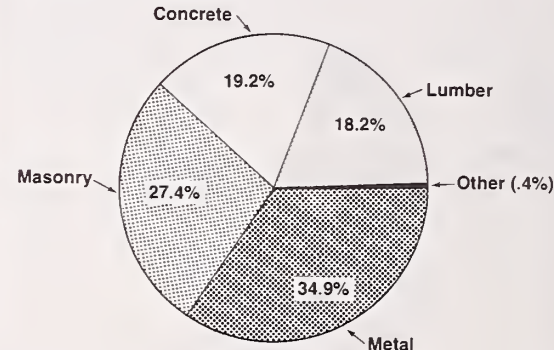
The 1982 survey was the most comprehensive study of this market and developed new information on the size and characteristics of nonresidential buildings. This information is vital to government and private researchers, market analysts, and industry marketers. It is particularly useful for projecting the demands for wood in this market and as an aid in devising products that meet this sector's specialized needs.



A grain storage building being built of wood instead of the usual metal.



Proportion of roofs built with different materials. Codes treat wood construction in roofs more leniently than in other building elements, resulting in a high incidence of use.



Proportion of exterior walls built with different materials. Noncombustible products dominate construction in this building element.

Analyzing the Issue of Below-Cost Timber Sales

Below-cost timber sales are among the most debated topics in forest management. Should the Forest Service participate in timber sales where the revenues generated are below the costs of selling the timber?

In analyzing this problem, Intermountain Station scientists determined that the desirability of a below-cost sale depends on and cannot be evaluated apart from the managerial context within which the Forest Service operates. The Station's report states that timber sales, whether below cost or not, must be assessed in terms of how they fit into

a comprehensive program of management for a National Forest. This involves regulations and complex administrative, statutory, and case law that clearly calls for systematic, integrative planning and management of National Forests for sustained, long-term production of multiple-use benefits to secure maximum net benefit to the public.

Study results indicate that, taken in this context, below-cost timber sales may be compatible with and even essential to optimal management of a National Forest.

Recreation associated with wildlife clearly has economic value. But how do you put a dollar value on experiences that aren't sold in the marketplace? How do such values stack up against stumpage values for timber?

If land managers are to respond to social needs and allocate scarce resources efficiently, they need the tools to get meaningful answers to questions such as these. Rocky Mountain Station research biologists and economists, and their cooperators, have completed a broad spectrum of studies on the economic value of hunting and fishing in Idaho. Using travel-cost and contingent-value methods, they estimated "consumer surplus" values per trip, per calendar day, and per wildlife and fish user day for many of the species and species groups sought by recreational hunters and anglers in Idaho. Included in the study are Idaho's "unique" species—mountain goat, bighorn sheep, moose, and antelope—plus elk, deer, upland game, waterfowl, warm- and cold-water fish, and steelhead.

Studies of this scope are rare. This effort involved the Idaho Department of Fish and Game, the USDI Bureau of Land Management and Fish and Wildlife

Service, the Army Corps of Engineers, and the Forest Service.

Dollar value estimates of hunters' and anglers' consumer surplus measures their willingness to pay for outdoor experiences over and above actual cash expenditures. Values per trip are highest for activities associated with the relatively rare mountain goat (\$360) and bighorn sheep (\$239) and lowest for generally available activities such as upland game hunting (\$35) and warm-water fishing (\$42). The size of consumer surplus values is related to the scarcity of the opportunity to hunt or fish for particular species and the expenditure needed to support the activity.

The values found in this study do not reflect the total intrinsic worth of the particular species involved. Rather, these estimates are an index of people's willingness to pay for particular hunting and fishing experiences.

Even though the primary purpose of the study was to evaluate nonmarket hunting and fishing benefits, it also demonstrated how such efforts could be implemented by government agencies or private organizations in other locations.

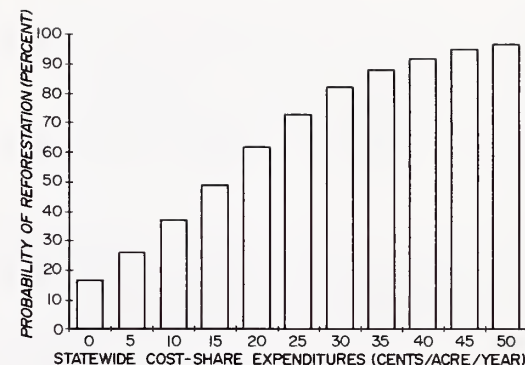


Cost-Sharing Programs Stimulate Forest Management

For many years Federal and State governments have tried to encourage forest management by sharing part of the cost of reforestation and other beneficial treatments. The programs have taken various forms, but their purpose has remained the same—to stimulate forest management by owners of small forest tracts. With public funds in short supply, the effectiveness of most public programs has been questioned, and forestry programs are no exception.

Some people have argued that public monies spent in this manner are simply substituted for private monies that would have been invested if the incentives programs did not exist. Critics have claimed that management activity would be about the same with or without the programs. Careful analysis by an economist at the Southeastern Station shows that this criticism is not justified.

In various years and in various places, the amounts of support offered in public programs have varied widely. Results show that forest management activity by small landowners has been considerably higher when and where incentives programs are effective in stimulating forest management on small tracts.



Public expenditures to stimulate forest management bear a direct relation to increases in the probability that harvested areas will be reforested.

The recent economic downturn has curtailed lumber production and closed mills in many places. As a result, the forest products industry is concerned about its competitive position in both domestic and world markets.

Researchers at the Pacific Northwest Station are studying the effects of the exchange rate on international trade in lumber. Exchange rates are an important factor in national and international softwood lumber trade and must be taken into account when formulating trade policy. Previous studies indicate that (1) an increase in the value of domestic currency relative to the currencies of trading partners encourages imports and acts as subsidy for foreign producers, and (2) an increasing exchange rate

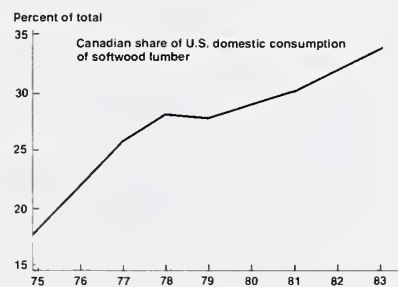
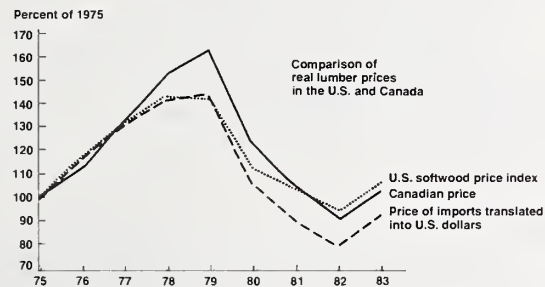
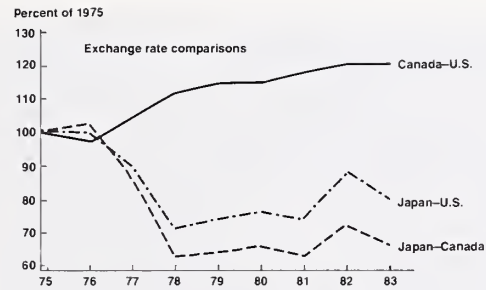
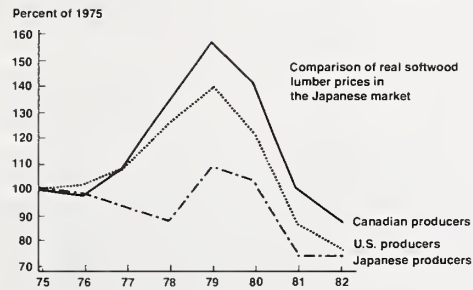
discourages exports and acts as a tax on domestic producers. As a result, exchange rates help explain the influx of Canadian softwood lumber into U.S. markets, and also indicate the relative competitive position of U.S. producers in the Japanese market.

The price Canadians get for lumber shipped to the United States can be computed from the price paid here for Canadian products. A comparison of real prices in the two countries shows that Canadian producers received higher prices than U.S. producers between 1978 and 1981. The result was an increase in the Canadian producers' share of the U.S. market.

Since the late 1970's, North American lumber producers have noted the potential for increased export of

softwood lumber to Japan. Exchange rates will partially determine the relative share of the Japanese market that the United States and Canada can expect to gain.

Implications of exchange rates can be examined by converting the Japanese price for softwood lumber into real prices in the United States and Canada. For 1977-82, U.S. producers received a price lower than that received by Canadian exporters to Japan (producers in both countries are assumed to incur equal transportation costs). Canadian producers have an incentive, because of the exchange rate, not only to increase their share of the U.S. softwood market but also to increase their share in the Japanese market.



During the fifth inventory of Georgia's forest resources, Forest Service scientists gave special emphasis to the incidence and source of timber damage. A special report concluded that hardwoods had more damage than softwoods, and more saplings were damaged than poletimber or sawtimber. The greatest value loss was in softwood sawtimber. The value of annual losses for softwood sawtimber in Georgia was \$96 million compared to \$41 million for hardwood sawtimber, even though more volume loss was estimated for hardwoods. In poletimber, the \$28 million softwood loss was many times that of hardwoods. Diseases, insects, and weather were the most prevalent damaging disturbances encountered. Recommended treatments include thinning, cleaning, salvage, harvest, or regeneration. This type of information is vital for the implementation of a successful pest management program. By knowing the types of damage present, the relative incidence, and the damaging agents involved, forest managers can design more effective and efficient controls.





Products and Harvesting

FPL Spaceboard

Research on the Forest Products Laboratory (FPL) press drying process for paper has resulted in a new structural fiber concept called FPL Spaceboard, a two-ply laminate that has the appearance of a three-ply sandwich (a panellike material with dense strong facings subtending a low-density core). The principal value of this new material is its ability to use low-quality wood pulp fiber in a high-performance structural product.

FPL Spaceboard is made by press drying fibers against a wafflelike mold. Coming off the mold, it looks like a fiber tennis-shoe sole. Put two of these together with the flat sides outside, using an appropriate adhesive, and the panel is complete.

While the FPL plans to pursue panel structures of various dimensions, the first FPL report on Spaceboard describes a panel comparable in weight and thickness to commercial C-flute corrugated fiberboard. For the same weight of fiber, the FPL Spaceboard (using high-yield hardwood fiber) was found to be from 30 to 200 percent stronger in edgewise compression strength than typical strengths for a commercial board made from low-yield softwood pulp.

Thus far, FPL Spaceboard has been made only in small laboratory samples, but FPL scientists are working on newer concepts that will allow for continuous production. Potential products from the Spaceboard process include containers, paneling, storage tanks, and mobile homes.



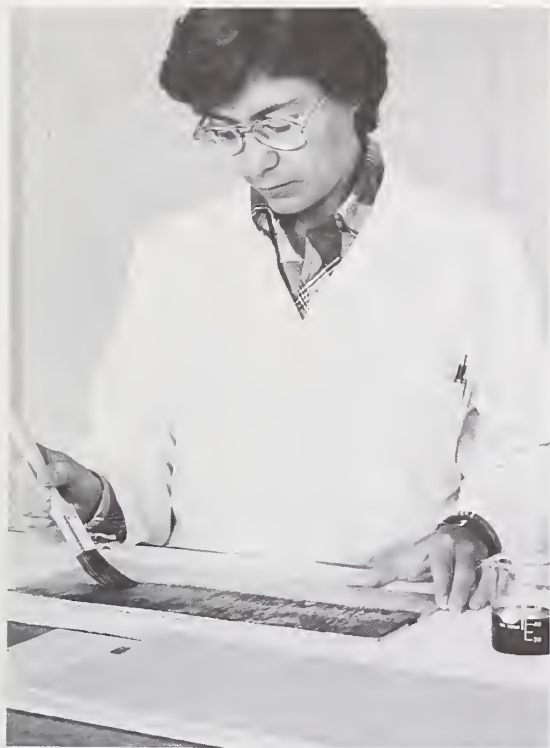
FPL wood technologist Vance Setterholm discusses the potential uses for Spaceboard.

During the last 25 years, petroleum-derived phenol-formaldehyde resins have been the most common adhesive used to produce weather-resistant wood products. The energy crisis of the 1970's, the high cost of phenol, and the inevitable decline in petroleum reserves prompted research aimed at replacing a large part of the petroleum-derived adhesive components with a readily available, renewable material that does not sacrifice high durability or bonding ease. This could lower the cost of bonded wood products and thus benefit the manufacturer and the consumer.

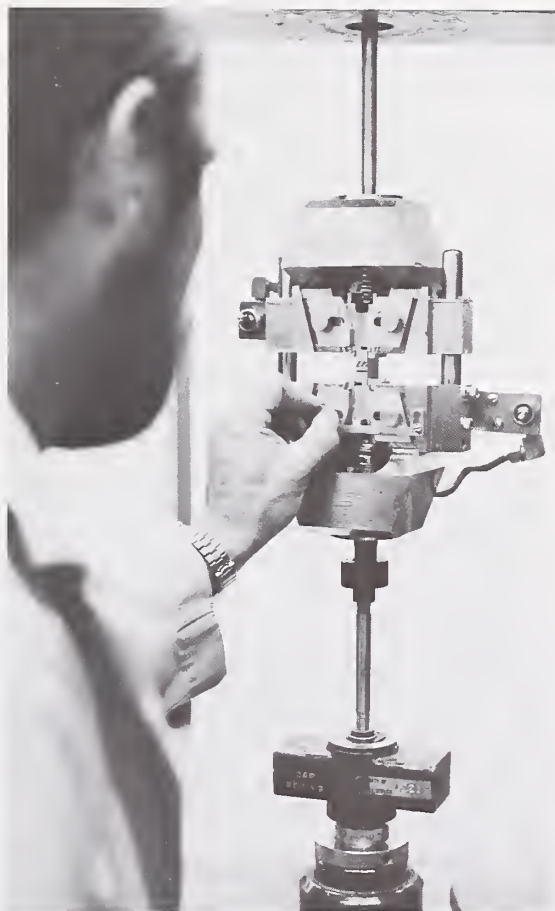
Researchers at the Forest Products Laboratory in Madison, WI, have shown that carbohydrate derivatives can replace up to about 50 percent of the components in phenolic adhesives now used to bond wood-based panel products. The carbohydrate derivatives can be obtained from wood, from byproduct streams of various wood manufacturing processes, or from other renewable biomass sources.

Plywood panels can be bonded with carbohydrate-modified phenol-formaldehyde adhesives at temperatures and pressures similar to

those now used commercially to make bonded wood products. The panels have dry- and wet-shear strengths equivalent to those of conventional phenol-formaldehyde adhesives. Durability tests show that when failure occurs, it takes place predominately within the wood and not the bondline. Further research is now underway to optimize bonding with the carbohydrate-modified adhesives and to determine how the chemistry of the modified adhesives differs from that of conventional phenol-formaldehyde adhesives.



Spreading carbohydrate-modified phenol-formaldehyde adhesives on Douglas-fir veneer prior to bonding plywood test panels.



Carbohydrate-modified phenol-formaldehyde adhesives developed at the Forest Products Laboratory are tested by the standard plywood shear test to evaluate their performance.

Industry, the Forest Service, and the university sector joined forces to develop a computerized design procedure for stringer-type pallets, the Pallet Design System (PDS). PDS is a computer program that allows pallet manufacturers to estimate the strength, deformation, and durability of a wood stringer pallet in a given handling environment to determine the specific pallet design suitable for a desired task. It also provides reliable predictions of the economic life and cost to use the pallets in a wide range of materials-handling environments. In short, PDS provides the industry a standard procedure for designing acceptably safe and acceptably economical pallets for any intended use.

Nearly 40 pallet manufacturers are currently using the PDS computer program, which has been programmed in BASIC for the IBM PC and Apple II+ computers. PDS is copyrighted by the National Wooden Pallet and Container Association, which provides the program to pallet producers on an annual lease basis. The proceeds are dedicated to financing future research.

The Pallet Design System is a product of a 4-year cooperative research

program conducted by Virginia Polytechnic Institute and State University, the National Wooden Pallet and Container Association, and the USDA Forest Service's Forestry Sciences Laboratory (Princeton, WV) and the Forest Products Laboratory (Madison, WI). Further research is already in progress by Virginia Polytechnic Institute with joint funding from the pallet association to expand PDS to cover block-type pallets and plywood pallets, and to develop more data on physical properties of pallet materials.

The Pallet Design System (PDS) provides the pallet industry a standard procedure for designing safe and economical pallets.



Preventing High-Temperature Corrosion When Machining Wood

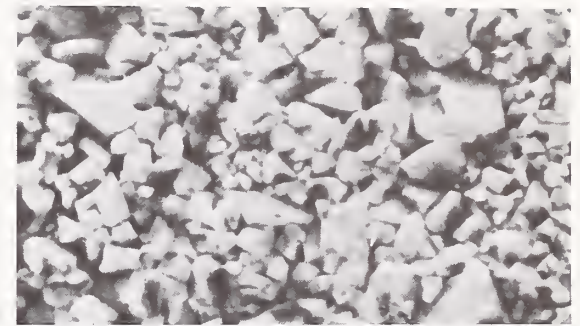
The inevitable dulling of cutter blades when machining dry wood and reconstituted wood products has traditionally been attributed to abrasion—the mechanical wearing away of the tool's edge. However, recent research at the North Central Station, in cooperation with others, has shown that high-temperature corrosion, not abrasion, is the major culprit in wood machine tool wear. High-temperature corrosion is generally the result of a chemical reaction that forms a salt deposit on a metal or oxide surface during the combustion of fossil fuels. In machining dry wood and wood products, this occurs when the tool slides through a series of oxidizing and reducing agents, inherent in such wood, accompanied by high temperatures and pressures. The rate of corrosion depends mainly on tool and workpiece composition and shape as well as ambient conditions.

Even high-speed tool steel and tungsten carbide can be corroded. The point of attack varies with the temperature and thus the speed of the machine. At high speeds, the tungsten carbide grains break down; at lower speeds, the cobalt binder is most vulnerable. With this in mind, tests were made showing that tool wear can be reduced by using materials or

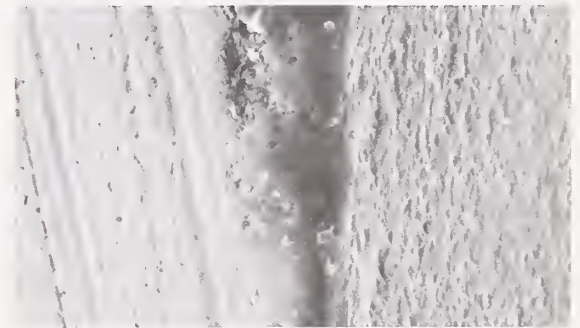
treatments that render the tool chemically inert at high temperatures and/or conduct heat away from the cutting zone. Also, because tool wear is caused by complex chemical reactions, many of the substances (adhesives, finishes, laminates) used in manufacturing reconstituted wood products like fiberboard could be modified to reduce tool wear. Other tool material properties, such as thermal expansion and thermal shock, should also be considered. For example, using a new ceramic or borided C2 tungsten carbide knife can greatly lessen tool wear when machining wood or wood-base products. This information has prompted some machine tool manufacturers to try new tool materials and manufacturing methods and new surface treatments.



Boriding C2 tungsten carbide can reduce the etching effect when machining wood and wood products. No evidence of abrasion is apparent.



The chemically "etched" effect of a C2 tungsten carbide along the edge after cutting medium-density fiberboard. No evidence of abrasion is apparent.



A new, tough ceramic tool material showed less wear than C2 tungsten carbide after cutting medium-density fiberboard. Again, no apparent abrasion on the rake face (right).

The long-term durability of fire-retardant-treated shingles exposed to outdoor weathering has been questioned in the past. Most treatments are evaluated for durability with accelerating weathering procedures. To answer the question of outdoor durability, scientists at the Forest Products Laboratory evaluated the effectiveness of various fire retardant treatments exposed after 2, 5, and 10 years on an outdoor weathering test fence in Madison, WI. The scientists also compared the actual outdoor results with accelerated weathering results in order to assess the capability of accelerated weathering procedures in predicting outdoor durability.

After 2, 5, and 10 years, the shingles were removed from the test fence and evaluated by two fire test methods: an ASTM E 108 burning brand test and a modified Schlyter vertical flame spread test. Nine out of 15 treatments passed the burning brand test while only one treatment, the commercial control, remained effective in the Schlyter test after 10 years' exposure. This information represents the only data available for long-term durability studies of exterior fire-retardant-treated shingles and shakes.

In comparing the accelerated weathering tests with outdoor exposures, scientists found that 1,000 hours of ultraviolet light and water spray in an accelerated weathering chamber was equivalent to only 2 years of outdoor exposure. To evaluate longer term durability, modifications

are needed in accelerated weathering procedures.

After 2, 5, and 10 years, Forest Products Laboratory scientists evaluated the long-term durability of 15 exterior fire-retardant treatments for cedar shingles and shakes on this test fence in Madison, WI.



Environment

Watershed Management

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**Forest and Range Experiment Stations,
Forest Products Laboratory**

Legend:

- ★ National Headquarters
- Forest and Range Experiment Station Headquarters
- ▲ Forest Products Laboratory
- Research Project Locations

Regions and Key Locations:

- Pacific Northwest:** Seattle, Olympia, Wenatchee, Portland, Corvallis, Bend, La Grande, Boise, Moscow, Fairbanks, Anchorage, Juneau.
- Pacific Southwest:** Berkeley, Fresno, Riverside, Redding, Arcata, Reno, Flagstaff, Tempe, Albuquerque, Flagstaff, Tempe, Albuquerque, Flagstaff, Tempe, Albuquerque.
- Intermountain:** Bozeman, Rapid City, Laramie, Wyoming, Ft. Collins, Colorado, Ogden, Provo, Logan, Idaho, Nevada, Arizona, California, Hawaii.
- Rocky Mountain:** Rapid City, Laramie, Wyoming, Ft. Collins, Colorado, Ogden, Provo, Logan, Idaho, Nevada, Arizona, California, Hawaii.
- North Central:** St. Paul, Grand Rapids, Duluth, Houghton, Rhinecland, Madison, East Lansing, Chicago, Indiana, Lincoln, Nebraska, Kansas, Oklahoma, Texas, New Mexico.
- Northeastern:** Broomfield, New York, Warren, State College, Pennsylvania, Maryland, Delaware, Washington, D.C., Research Triangle, Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Arkansas, Missouri, Illinois, Kentucky, Tennessee, West Virginia, Pennsylvania, New Jersey, New York, Connecticut, Massachusetts, Rhode Island, Vermont, New Hampshire, Maine.
- Southeastern:** Asheville, Clemson, Marion, Charleston, Gainesville, Florida, Auburn, Stoneville, Oxford, Mississippi, Alabama, Georgia, South Carolina, North Carolina, Virginia, West Virginia, Kentucky, Tennessee, Mississippi, Louisiana, Arkansas, Missouri, Illinois, Kentucky, Tennessee, West Virginia, Pennsylvania, New Jersey, New York, Connecticut, Massachusetts, Rhode Island, Vermont, New Hampshire, Maine.
- Southern:** Monrovia, Stoneville, Oxford, Mississippi, Alabama, Georgia, South Carolina, North Carolina, Virginia, West Virginia, Kentucky, Tennessee, Mississippi, Louisiana, Arkansas, Missouri, Illinois, Kentucky, Tennessee, West Virginia, Pennsylvania, New Jersey, New York, Connecticut, Massachusetts, Rhode Island, Vermont, New Hampshire, Maine.
- Pacific Islands Forestry:** Honolulu, Hawaii.
- Institute of Tropical Forestry:** Puerto Rico.

